# Popular Astronomy

Vol. LVII, No. 8 OCTOBER, 1949 Whole No. 568

## The Impress of Past Ages in Modern Astronomy

By EDGAR W. WOOLARD

From the viewpoint of an interest primarily in astronomy rather than in history as such, the history of astronomy is principally of interest not as a chronicle of successive historical events but as a record of the progressive development of thought through which the complex system of modern astronomical concepts, principles, and methods has *historically* been established, as distinguished from the direct reasoning by which this system may now be *logically* constructed. From this point of view, it is the history of the development which originated among the empires of the ancient Near East, especially in Babylonia, that is of primary importance. Modern astronomy, when its history is traced back, is found to be the outcome of an unbroken development beginning in Babylonia more than 2500 years ago and successively continued by the Greeks during ancient times, by the Moslems during the medieval period, and in western Europe after the Revival of Learning; except for limited secondary contributions from ancient Egypt and India, it was never significantly influenced by the astronomical learning which grew up among other early civilizations.

The impress of every period of this long history may be recognized in modern astronomy. During the earlier periods, astronomy was practically limited to the systematic observation and discussion of the apparent positions and motions of the Sun, the Moon, the planets visible to the unaided eye, and the brighter stars; and to theoretical interpretations and mathematical representations of the observed motions, by means of which they and their attendant phenomena, such as eclipses, could be predicted. It is therefore in the classical astronomy of position that the imprint of the more remote past appears. It is immediately apparent in astronomical terminology—not only in our familiar heritage of the constellations, with the legends of ancient times woven about them, and in the proper names attached to the brighter stars, but also throughout the technical vocabulary of astronomy, where many terms embody an implicit record of the genesis and evolution of concepts, and of former modes of thought; and it is also reflected in the many concepts, principles, and practices of modern astronomy which either are a direct heritage from a former age when they were first established or else retain characteristics of former ideas from which they have been directly derived.

The great extensions into sidereal astronomy and astrophysics in modern times, and their rapid advances during recent years, have overshadowed the longer established knowledge inherited from earlier periods; and in the classical astronomy itself, the change in many concepts since ancient times has been so great—*e.g.*, in the planetary theory—that it tends to obscure the direct dependence on the past, and the extent to which a heritage from former times still explicitly remains. However, the astronomy of position is the indispensable foundation and framework of the entire modern system; and a realization of the way in which the now accepted fundamental concepts and principles have actually developed historically from the primitive beginnings of astronomy in remote times, and an appreciation of their proper relations to former modes of thought, are effective aids in obtaining an insight into the foundations on which modern astronomy depends.

In particular, it is important to recognize the *continuity* of the historical development by which, from the astronomy of ancient Babylonia and Greece, modern astronomy has lineally descended. This development has been no exception to the general rule that the progress of scientific thought is nearly always a gradual evolution of ideas by a succession of comparatively small steps which at the time are each a natural extension or immediate modification of the preceding. The *cumulative* result after a sufficient length of time, however, may be a transformation so profound that if it had been made in one step it would amount to a revolution in thought, and when, *e.g.*, the history of 2500 years of the planetary theory is limited to a synopsis of a few principal stages separately, such as the Ptolemaic, Copernican, and Keplerian systems, a misleading impression may be produced; but historically, each successive theoretical system was developed directly from the preceding by explicit revisions, which often depended on many intermediate modifications, and by which one system was progressively transformed into the other. The astronomers of every period continued from where their predecessors had left off, and based their further advances directly on the accumulated results transmitted from the past.

In particular, the ancient Ptolemaic astronomy is the immediate *historical* foundation on which the modern developments that now constitute the *logical* foundation of astronomy were explicitly based; these later developments, instead of being independent conceptions that completely overthrew Ptolemaic astronomy, were directly derived from it by successive revisions in which the previous structure was modified and progressively reconstructed. Ptolemaic astronomy was amply comprehensive in scope, scientific in character, and advanced in development to constitute an adequate basis for these modern developments; the high level reached in the sciences at an early period in ancient times is not commonly accorded proper recognition—it is unfortunate that disproportionate attention is usually given to the Greek speculative philosophers, while technical scientific achievements are relatively neg-

lected or disparaged.[1] An authentic record of Ptolemaic astronomy is extant in Ptolemy's own great treatise, the *Syntaxis Mathematica,* usually referred to as the *Almagest,* written in the second century A.D.; and because of the progressively greater difficulty encountered in tracing the history farther into the past, as the extant records become increasingly incomplete, the *Almagest* is a convenient central point in the history of astronomy, from which to trace the development of thought forward to modern times and to extend it back toward its beginning as well as possible.

The *Almagest* makes a printed volume of about 800 pages,[2] and contains: an exposition of trigonometry, and its application to the solution of the principal problems of spherical astronomy; descriptions of the instruments then in use, and methods of observation; a treatment of precession; a star catalogue; mathematical theories of the motions of the Sun, Moon, and planets, and tables for the computation of ephemerides; determinations of the sizes and distances of the Sun and Moon; and methods for mathematically predicting solar and lunar eclipses, and planetary phenomena.

This system of astronomy, constructed by mathematical reasoning based on centuries of accumulated observations, was the outcome of Greek and Babylonian developments extending back into ages which even Ptolemy refers to as ancient; and it includes comparatively little which can be adversely criticized.[3] It is based on the physical hypothesis of a stationary spherical Earth at the center of the universe. Ptolemy adopts this hypothesis after also expressly considering the alternative hypothesis of a moving Earth as a possible interpretation of immediate appearances; his decision in favor of a motionless Earth was not universally accepted among the Greeks, but may reasonably be considered to have been at the time the more logical conclusion from the evidence then available, and was the one that most generally prevailed. In the planetary theory, the object was to represent the observed apparent motions on the celestial sphere by means of combinations of uniform circular motions in space. This method was intended only as a formal mathematical representation for purposes of calculation, not as a theory of the physical construction and mechanism of the system; mathematical astronomy had already separated from philosophy, and no longer included cosmology. The technical details of the Ptolemaic planetary

[1] The recent anthology of Greek science by Morris R. Cohen and I. E. Drabkin, "Source Book in Greek Science," New York, 1948, should dispel any illusion that natural science began in the 16th century; this volume includes an extensive section on astronomy.

[2] The most authoritative version of the Greek text is the edition by J. L. Heiberg, *Claudii Ptolemaei opera quae exstant omnia,* Vol. I, Leipzig, 1898-1903; it was translated into German by Karl Manitius, *Des Ptolemäus Handbuch der Astronomie,* Leipzig, 1912-1913. A Greek-French edition by Halma, *Composition mathématique de Claude Ptolémée,* originally published 1813-1816, was photographically reprinted at Paris in 1927.

[3] *Cf.* Louis O. Kattsoff, Ptolemy and Scientific Method, *Isis,* **38**, 18-22, 1947.

theories need not be given here, as they are readily available elsewhere.[4] These theories are constructed by systematically resolving the complex actual apparent motions into artificial simple components, each representable by a uniform circular motion in space; the rates of these component motions, and other necessary parameters, are determined from long series of appropriate observations. In mathematics, the Greeks were preeminently geometers, and this method is the geometric counterpart of the modern analytic methods of representation by series of trigonometric terms.

The *Almagest* remained the almost universally accepted standard authority for 1400 years—in the East after the fall of the Roman Empire, among the Moslems during medieval times, and in western Europe from the Revival of Learning until the Renaissance.

In practical astronomy, the ancient instruments and methods of observation, modified only in details, remained in use until, beginning during the 17th century, they were gradually superseded by the early forms of modern instruments and methods that were introduced by Gascoigne, Picard, and Roemer, and which were first extensively applied in the early 18th century by Flamsteed and Bradley. These modern developments were to a large extent due to the introduction of the pendulum clock; in ancient and medieval astronomy, the lack of any means for the accurate determination of time had been one of the greatest handicaps, and is the most severe limitation on the usefulness of ancient observations for modern purposes.[5] In addition, the application of the telescope in positional astronomy, and the introduction of the micrometer, led to a new order of accuracy in astronomical measurements. As data accumulated, many of the former methods by which measurements had been made were eventually replaced by improved procedures by which greater accuracy could be obtained, but which depended on having these previous results available.

In spherical astronomy, mathematical procedures were improved—*e.g.*, trigonometry was developed into a more expeditious form—but the basic concepts and principles have needed no fundamental change.

In the planetary theory, the successive modifications by which the Ptolemaic system was eventually transformed into modern form began with the critical revision of the *Almagest* written by Copernicus under the title *De Revolutionibus Orbium Coelestium*. In this celebrated treatise, which is very similar in form, content, and arrangement to the

[4] See, *e.g.*, A. Pannekoek, The Planetary Theory of Ptolemy, POPULAR ASTRONOMY, **55**, 459-476, 1947; and O. Neugebauer, Mathematical Methods in Ancient Astronomy, *Bull. Amer. Math. Soc.*, **54**, 1013-1041, 1948. The *Almagest* itself should also be consulted.

[5] For examples of the importance of accurately timed ancient observations, see: J. K. Fotheringham, Two Babylonian Eclipses, *Mon. Not. Roy. Astr. Soc.*, **95**, 719-723, 1935. P. V. Neugebauer, Ein Keilschrifttext von grösster Bedeutung für die moderne Astronomie, *Die Naturwissenschaften*, **20**, 169-170, 1932. P. V. Neugebauer, Eine Konjunktion von Mond und Venus aus dem Jahre —418 und die Akzeleration von Sonne und Mond, *Astr. Nach.*, **244**, 305-308, 1932.

*Almagest,* the center of the planetary system is transferred from the Earth to the Sun, but the Ptolemaic system of eccentrics and epicycles is otherwise left practically unchanged—Ptolemy's methods were adapted to the heliocentric hypothesis, and his system was reformulated on this basis.

The motion of the Earth was advocated by Copernicus as a physical principle; but no additional evidence had become available since ancient times on which to base an actual decision between the geocentric and heliocentric hypotheses, and the question necessarily remained unsettled. Systematic observation, both during medieval times by the Moslems, and later in western Europe, had long before shown appreciable discrepancies between astronomical tables and the actual apparent motions; and many efforts had been made to remove these discrepancies by modifying the details of Ptolemy's theories, but no important progress had resulted. The need that was therefore apparent for a reconstruction of the planetary theory led Copernicus to return to the question, already considered in ancient times, whether the observed phenomena could be more satisfactorily explained on the hypothesis of a moving Earth. He was the first actually to construct mathematical theories and tables on this hypothesis;[6] they demonstrated that the observed motions could be represented by a heliocentric theory, but in the particular form in which the theory was formulated by Copernicus—as a mathematical transformation of the Ptolemaic system—it gave no significant gain in either accuracy or simplicity. The two systems were about equally effective as formal representations; and both continued in use as means of calculation, while the question as to which hypothesis was physically true remained controversial. Meanwhile, efforts continued to determine the actual motions more accurately by observation, and to bring the tables into agreement with them; and the next significant theoretical advance was made by Kepler, on the basis of Tycho Brahe's unsurpassed series of observations.

Adopting the heliocentric hypothesis, Kepler attempted to represent Tycho's observations by modifying the details of the Copernican system; and after many years of trial he empirically found that the planetary orbits are ovals, which he ascertained to be ellipses with the Sun at one focus. This *form* of the orbit may easily be generated by an appropriate epicycle and deferent, as Kepler points out, and in itself it does not represent any fundamental modification of the traditional system; but Kepler established the further fact that the *motion in this orbit* is not in accordance with the uniform circular motion that would be required to generate the ellipse by an epicycle, but that instead the radius vector describes equal areas in equal times. This law is Kepler's great contribution, and was the most fundamental advance in the plane-

[6] For details of the Copernican theories, see A. Pannekoek, The Planetary Theory of Copernicus, POPULAR ASTRONOMY, **56**, 2-13, 1948; Angus Armitage, *Copernicus,* London, 1938; and the *Commentariolus* by Copernicus himself, in Edward Rosen, "Three Copernican Treatises," New York, 1939.

tary theory since Ptolemy.[7] However, the traditional principle of uniform circular motions persisted among some of Kepler's contemporaries, who accepted the elliptic form of the planetary orbits but rejected the Law of Areas.

Kepler's empirically derived kinematical laws were recognized to be an indication that an influence exerted on the planets by the Sun is the physical cause of the planetary motions; but the suggestions made by Kepler and others as to the nature of this influence (among which was even the inverse square law) necessarily remained unproductive until after the laws of motion had been completely formulated by Galileo, Huyghens, and Newton.[8] Newton's identification of this influence with the same force that causes terrestrial gravity, and his establishment of the mathematical law of this force, completed the theoretical principles necessary for the physical explanation and exact calculation of the celestial motions.[9] At the same time, this physical interpretation of Kepler's Laws showed that these laws were not quite exact, because of the irregularities produced in the motions by the disturbing gravitational actions of the planets on one another; and the Keplerian ellipses were modified into highly complex and ever varying curves. The first systematic application of the Law of Gravitation to the construction of complete dynamical theories for all of the principal bodies of the solar system was by Laplace.[10]

The sequence of forms through which the gravitational heliocentric orbit was derived from the formal Ptolemaic representation was a continuation of an earlier development extending back to the primitive naive concept of the heavens as a rotating crystalline sphere, or series of concentric spheres, which had been introduced by the early Greek speculative philosophers. In this earlier development among the Greeks, Babylonian astronomy was an essential part of the foundation. Babylonian astronomy, although extending back to remote Sumerian times, remained primitive until the late Assyrian period, but reached a highly advanced stage in the third and second centuries B.C., at the time when in Greece, after a mythological and speculative period, rational scientific astronomy was rapidly developing.[11] The Greek astronomers made extended use of the Babylonian observations, and in early Greek astronomy the Babylonian methods were also adopted; but among the Baby-

[7] See Carl B. Boyer, Note on Epicycles and the Ellipse from Copernicus to Lahire, *Isis*, **38**, 54-56, 1947. A. Pannekoek, The Planetary Theory of Kepler, POPULAR ASTRONOMY, **56**, 63-75, 1948.

[8] See Boyer, *op. cit.*

[9] A. Pannekoek, The Planetary Theory of Newton, POPULAR ASTRONOMY, **56**, 177-192, 1948.

[10] A. Pannekoek, The Planetary Theory of Laplace, POPULAR ASTRONOMY, **56**, 300-312, 1948.

[11] For a general review of ancient Egyptian, Babylonian, and Greek astronomy, see O. Neugebauer, The History of Ancient Astronomy: Problems and Methods, *Publ. Astr. Soc. Pac.*, **58**, 17-43, 104-142, 1946. On Old Babylonian astronomy of the prescientific period, see also B. L. van der Waerden, Babylonian Astronomy II, *Jour. Near Eastern Studies*, **9**, 6-26, 1949.

lonians, the interpretation of observed phenomena apparently never progressed beyond the mythological stage, and their mathematical astronomy was entirely a direct empirical representation of the immediately observed motions, constructed by arithmetical methods,[12] in contrast with the later Greek geometrical methods. The Greeks, in addition to improving and further developing the Babylonian methods, introduced theoretical systems of motions in space for the purpose of mathematically representing the observed apparent motions on the celestial sphere. Their first attempts were inevitably influenced by prevailing philosophical ideas; and it was natural that the earliest theories should be based on the concept of rotating crystalline spheres, which is almost irresistibly suggested by immediate appearances.

The most obvious phenomena are readily coordinated in this way—*e.g.*, the apparent diurnal motion of the stars may be satisfactorily represented by the rotation of a material sphere on which the stars are fixed. By introducing separate spheres for the Sun and the Moon, which move continually eastward among the stars, the principal features of the apparent solar and lunar motions may similarly be represented, but critical comparison with continued observation soon shows details of the motions which require a refinement of this simple concept—in particular, the rates of motion of the Sun and Moon are variable, and the motion of the Moon has further complexities, requiring more than a simple uniformly rotating sphere to explain; and it is not obvious how the complex paths of the planets among the stars are to be explained at all in this way. However, by using a set of interconnected spheres for each body instead of only one sphere for each, Eudoxus in the early 4th century B.C., constructed a system of 27 uniformly rotating concentric spheres which was capable of representing the apparent motions of the Sun, Moon, and the five known planets, to an approximation that for the most part was as close as the motions had yet become known.

Four uniformly rotating spheres, *e.g.*, were required for each planet. The planet was fixed on the equator of the innermost of these spheres. The poles of the axis of this inner sphere were fixed on the next outer sphere, which rotated around a different axis at a different speed, carrying the inner rotating sphere around with it; likewise, the poles of this second sphere were carried on the third sphere, and the poles of the third on the fourth. As a result of the rotation of the innermost sphere, the planet moves uniformly in a circle centered at the Earth; but meanwhile this circle is continually moving in space as the inner sphere moves because of the rotations of the other three spheres. Consequently, the planet describes a complex curve in space which is the resultant of the four components determined by the rates of rotation and the rela-

[12] A. Pannekoek, Planetary Theories, POPULAR ASTRONOMY, **55**, 422-438, 1947. O. Neugebauer, Mathematical Methods in Ancient Astronomy, *Bull. Amer. Math. Soc.*, **54**, 1013-1041, 1948.

tive positions of the axes of the four spheres; and by properly fixing these axes and speeds, Eudoxus obtained a consequent apparent motion on the celestial sphere that represented the observed motion. The Sun and the Moon each required three spheres, and the stars one. Each set of spheres was independent of the other sets; and the Earth was at the common center of the system.[13]

This theory is the earliest known systematic attempt to represent quantitatively the details of the actually observed apparent motions by means of a theory of the arrangement and motions of the celestial bodies in space. Callippus, about 325 B.C., added six more spheres to improve the agreement with observation; and Aristotle further increased the total number to 55. It is highly probable that in astronomy this system of spheres was regarded only as an abstract geometrical construction for the purpose of computation. Aristotle, however, incorporated it into his philosophy as a theory of the physical constitution of the universe. In philosophy and theology, the weight of his authority was so great that this cosmology persisted into early modern times; but in astronomy, the homocentric spheres were rapidly superseded by more satisfactory theories, and moreover the attempt was definitely abandoned to find the physical construction of the universe—theoretical astronomy was limited to the construction of geometrical systems that would formally represent observations by means of combinations of uniform circular motions.

In the system of homocentric spheres, the orbit in space is generated by a uniform motion of the body in a moving circle centered at the Earth. The Greek geometers soon perceived that in the cases of the Sun and the superior planets, the complex motion which this circle must have may be simplified or entirely avoided by the simple and natural modification of displacing the center of the circle from the Earth. *E.g.*, the variable rate of the apparent annual motion of the Sun may readily be represented by a uniform motion of the Sun in a *fixed* circle *eccentric* to the Earth; the *apparent* rate of motion then varies inversely as the distance to the Sun, and by properly fixing the eccentricity or displacement of the center, and the direction to the apogee, the position of the Sun may theoretically be represented on this hypothesis to within about 1′.5—far more accurately than it could be observed in ancient times—although in practice this degree of accuracy was never actually realized because of the difficulty of determining the elements of the solar orbit with sufficient accuracy (*e.g.*, the length of the year determined by Hipparchus and Ptolemy was 6 minutes too great). Similarly, a *moving* eccentric may be used for the superior planets. This method will not succeed for Mercury and Venus; but the eccentric orbits of the other bodies may be geometrically represented as

[13] For details, see J. L. E. Dreyer, "History of the Planetary Systems," chap. IV, Cambridge, 1906; and Sir Thomas Heath, "Aristarchus of Samos," chap. XVI, Oxford, 1913.

the resultant of two uniform circular motions—a uniform motion of the body around a small circle or epicycle, and a uniform motion of the center of this epicycle around a large circle or deferent—and not only may this geometrical equivalent of the eccentric equally well be used for the Sun and the superior planets in place of the eccentric directly, but also this construction may be adapted to the inferior planets. This method probably was introduced by Apollonius in the third century B.C.; and on this basis Hipparchus and Ptolemy developed their elaborate mathematical theories of the planetary system.[14] The success of their constructions is due to the fact that as the Earth and the planets revolve around the Sun in their nearly circular elliptic orbits, the motion of a planet in space *relative to the Earth* is the same as if the Earth were at rest and the planet were moving both with its own motion and also with the opposite of the Earth's motion; and its *direction* from the Earth in this actual geocentric motion, upon which alone the observed apparent motion on the celestial sphere depends, may therefore be formally represented very closely by means of an appropriate epicycle and deferent,[15] although various refinements and accessory details are needed for the individual planets.

The subsequent adaptation of the Ptolemaic system to the heliocentric hypothesis by Copernicus, followed by Kepler's modification of the orbits to ellipses and his formulation of the kinematic laws of the motion in these elliptic orbits, formed the foundation on which the Newtonian dynamical theory was erected. Through more than 2000 years of continuous effort, the crystalline sphere had been transmuted into the gravitational orbit.

In addition to the historical influences and explicit imprints of the past in astronomy proper, many popular ideas, legends, and customs are traditions from the remote past which originally were directly associated with astronomical phenomena. In early times, the aspects of the heavens were much more intimately associated with the daily life, thought, and customs of the people than now; but many ideas and practices originating from these ancient associations still survive in some form—*e.g.*, in the division of the year into months, now conventional but originally an actual reckoning of time by the cycle of the phases of the Moon; in the religious calendars of the East, where along the Nile the traditional watch for the first appearance of the lunar crescent in the twilight sky is still kept by the Moslems, as it was by the ancient Babylonians, to determine the beginning of the month;[16] in popular customs and ideas such as Halloween—a degenerate survival of the dread rites of the ancient Druids at the midnight culmination of

[14] See Dreyer, *op. cit.*, chap. vii.

[15] See the diagrams in C. A. Young, "General Astronomy," Art. 1009, and J. C. Duncan, "Astronomy," 4 ed., pp. 212-213; *cf.* Simon Newcomb, "Popular Astronomy," 5 ed., pp. 38-39.

[16] J. H. Reynolds. The Mohammedan Calendar and the First Visibility of the New Moon in Egypt. *Occasional Notes Roy. Astr. Soc.*, 1939, Dec.

the Pleiades during the three-day festival held at that time of the year in memory of the dead[17]—and Dog Days, the Dies Caniculares of the Romans, associated among the Greeks and Romans with the heliacal rising of Sirius and the coming of the greatest heat of summer as the rays of the star blended with those of the Sun;[18] in many religious holidays, such as Christmas, which represents a Christian counterpart and continuation of the former pagan festivals celebrating the occurrence of the winter solstice as the Sun commenced its return journey northward;[19] in the ecclesiastical lunar calendar, which is based on the Metonic Cycle of the Greeks and the Babylonians; and in some technical practices such as the familiar sexagesimal systems of measuring time and angles, which have been transmitted from ancient Babylonia and Egypt by way of Greek astronomy and mathematics. The manifold associations of celestial phenomena with these traditions during immemorial ages in all the lands of the Earth impart a romantic fascination to the natural beauty and mystery of the heavens.

The historical aspects of astronomy and its associations with the traditions of the past receive more attention in the older astronomical books than in modern writings;[20] to lose sight of them, however, and confine attention to modern technicalities and logical exposition alone, is to neglect a factor of great importance in the appeal and general interest of astronomy.

[17] J. F. Blake, "Astronomical Myths," London, 1877, (an English version of Flammarion's "History of the Heavens").

[18] R. H. Allen, "Star-Names and their Meanings," pp. 126-127, New York, 1899.

[19] Wm. H. Barton, Jr., Christmas Story, *Sky and Telescope*, 1941, Dec.; Karel Hujer, Christmas and the Stars, POPULAR ASTRONOMY, **53**, 486-489, 1945. Karel Hujer, The Astronomical Significance of Easter, POPULAR ASTRONOMY, **54**, 131-135, 1946.

[20] An exception is the delightful book by Stephen A. Ionides and Margaret L. Ionides, "One Day Telleth Another," London, 1939; an American edition was issued with the title, "Stars and Men."

U. S. NAVAL OBSERVATORY, WASHINGTON, D. C.

# Joseph Haines Moore*

## 1878-1949

Joseph Haines Moore joined the staff of Lick Observatory in 1903. He was retired from active service a few months before his death, which occurred on March 15, 1949. For the greater part of his life he devoted a singularly lucid and inquiring mind to the service of the University and the Observatory.

Moore was born in Wilmington, Ohio, on September 7, 1878, the only child of John Haines Moore and Mary Ann Haines. His parents

*Reprinted from *University of California Faculty Bulletin*, Vol. 19, No. 1, pp. 7-8, July, 1949. Communicated by Dr. Frederick C. Leonard of the University of California, Los Angeles.

were members of the Society of Friends, with long lines of Quaker ancestry, and Joseph was raised in the wholesome discipline of that sect; in youth and manhood he held to its philosophy of conduct, and he maintained his relations with the Society throughout his life.

Following his elementary education, Moore attended Wilmington College. He took the classical course, and received the A.B. degree in 1897. While his studies there did not especially fit him for the career of scientific research to which he devoted his later years, he came, happily, in his senior year, under the inspiring influence of Professor W. Bennett, an enthusiastic teacher of astronomy, from whom he acquired the deep and lasting interest in that subject, and in the broad field of science, which characterized him during the remainder of his life.

The immediate consequence of Moore's collegiate experience was that he entered Johns Hopkins University with the purpose of studying astronomy under Simon Newcomb, then the most eminent astronomer in this country. At the university, however, he found his preparation for advanced study in sciene to have been inadequate, and it was necessary for him to take two years of undergraduate work. At Johns Hopkins he came under the instruction of Newcomb, in astronomy, and of Rowland, Ames, and R. W. Wood in physics. His major study was in the latter field, and he received the degree of Doctor of Philosophy in 1903. He came at once to Mount Hamilton, and entered upon his career as an astronomer.

Moore began as assistant to W. W. Campbell in the measurement, by means of the spectroscope, of the velocities of the stars in the line of sight. Dr. Campbell had, a few years before, initiated a large undertaking in that field, but in the meantime had been appointed director of the Observatory. The management of a scientific institution in so isolated a situation as Mount Hamilton demands attention to a multitude of administrative details, and it was essential that the new assistant take over as much of the spectroscopic observation as possible. The work was of a pioneer character, and the strategic position of stellar radial velocities in the general astronomical scheme was beginning to be realized. The environment was one in which the interest of a young scientist might be expected to expand, and Moore, profiting by the opportunity afforded him, became a recognized authority in that important field of inquiry. The demands upon Campbell's time continued to grow, culminating in 1923 in his appointment to the presidency of the University, and Moore was eventually obliged to assume the major responsibility for the conduct of the radial-velocity program. The work was completed in 1928, through the publication by Campbell and Moore of their great catalogue of stellar radial velocities. The catalogue is accompanied by a comprehensive discussion of the observations, a redetermination of the elements of the solar motion, and provides a very complete history of the Lick Observatory radial-velocity project. It constitutes

the most extensive and homogeneous body of information relative to the radial velocities of stars that has appeared.

Among the objects of Moore's particular attention were the spectroscopic binary stars. These are stars which in the most powerful telescopes appear single, but which spectroscopic examination shows to be double. He discovered many of these interesting objects, and calculated their orbits. The field is an important one, and touches many other areas of astronomical knowledge; it requires close discrimination in the interpretation of observations, and in it Moore was preëminent. The circumstances of Moore's work brought him into contact with problems of a widely varied character, in the development of which he actively participated, and which in turn contributed to the breadth of his scientific outlook. He never developed the channeled interest of a close specialist.

From his early position as assistant, Moore passed through the regular grades to that of astronomer. In 1936 he became assistant director of the Lick Observatory, and in 1942, director. He served on five of the Observatory's eclipse expeditions to various parts of the world, and was in direct charge of two of them. He was acting astronomer in charge of the Observatory's southern station, at Santiago, Chile, from 1909 to 1913. Beginning in 1944 he suffered some distress caused by the altitude of the observatory, and on November 30, 1945, following the advice of his physician, he relinquished the office of director, and was transferred to Berkeley. There he gave instruction in the University and engaged in research until his retirement on September 6, 1948. While in Berkeley he enjoyed apparently normal health. On the morning of March 15 he died during sleep. He was a member of the principal learned societies within the fields of his interest, and of the National Academy of Sciences.

To astronomers in many lands Joseph Moore is known as the source of a great amount of dependable information that they require in their own researches. His colleagues remember him as an able and resourceful observer, and above all as a warm and loyal friend. Perhaps the students and younger members of the staff found themselves more in his debt than any of the other participants in the observatory life. These young people came to him for advice on likely subjects for research, and he gave unstintingly of ideas that he might have used to his own professional advantage had he not been burdened with routine work. Through suggestion, guidance, and actual physical help, he set students upon careers that have brought credit to the University of California and to the Lick Observatory.

On June 12, 1907, Dr. Moore was married to Miss Fredrico Chase, of Payette, Idaho, a graduate of Vassar College, who had come to the Lick Observatory as an astronomical assistant in 1905. Their association was an ideal one and brought happiness to the observatory community as well as to themselves. They had two daughters: Mary Kath-

ryn (Mrs. H. Vern Gates) and Margaret Elizabeth (Mrs. Vinton S. Matthews). Dr. Moore is survived by Mrs. Moore, their two daughters, and five grandchildren.

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# Magnetic Observations at Abinger, England*

A branch of the Royal Greenwich Observatory has been at Abinger for nearly 25 years, but visitors in the district, and, in fact, many local residents have only a very vague idea of the nature of the work which is carried on there. It may therefore be of some interest to describe briefly why an observatory station is at Abinger, and what work is carried on there.

The work of the Royal Observatory covers a wide range, and is not restricted to astronomical investigations and observations alone. In 1840, while Sir George Airy was Astronomer Royal, a "Magnetic Department" was started. A predecessor of Airy, the famous Halley whose name is remembered widely for his prediction of the return of a comet, had made many systematic observations of the magnetic field of the earth nearly 150 years previously. Under the guidance of Airy, however, regular observations of the variations in the direction and strength of the earth's magnetic field were instituted. At first these observations were made visually but, within a few years, continuous automatic photographic registration was introduced. Greenwich was the first Observatory to employ photography to obtain continuous records of the variation of the earth's magnetism, and similar records, but with far more accurate and modern instruments, are still being obtained.

In 1923, the electrification of England's Southern Railway suburban system made it impossible to continue the magnetic observations at Greenwich. The site at Abinger was chosen since this was, at that time, free from artificial disturbance. Improved instruments were installed, and the high standard of precision obtained has received world-wide recognition. In addition to routine measurements, special magnetic instruments required for survey work abroad are tested at Abinger, and facilities are provided for commercial firms wishing to obtain a certificate of performance for the most accurate instruments. However, the electrification of the Southern Railway has now made this site also unsuitable, and it is planned to remove the magnetic work to the West of England.

*From the Department of the Chief of Naval Information of the British Admiralty in London.

### Time Department

Another important and far better known activity of the Royal Observatory is the control and operation of the National Time Service. The standard of time is the period of rotation of the earth, and the determination of time is thus an astronomical problem. The standard clocks, used for the control of time signals, are regularly checked by means of star observations. The well-known "six pips" time signals radiated by the B.B.C. are only one form of time signals controlled from the Royal Observatory. There are also precision radio time signals, radiated twice daily from long and short-wave transmitters at Rugby and these are recorded all over the world. The Observatory also receives and measures radio time signals from other countries, and the time systems of various countries are continuously intercompared.

Shortly before the outbreak of war, it was realized that under war-time conditions it might become difficult to continue the control of the time service from Greenwich. Since the station at Abinger was already available, some equipment was installed there to serve as a reserve, and regular astronomical observations were commenced in order to provide an effective link with Greenwich. When the night air-raids on London commenced, time service work at Greenwich was suspended, and the control of the service taken over by the Abinger station. At the same time, a reserve service was started at the Royal Observatory, Edinburgh. Throughout the war, the time service was thus maintained jointly from Abinger and Edinburgh, and, although on some rare occasions one or two signals were missed,—usually owing to damage to land-lines immediately before the signals were due,—the time service was kept in continuous operation throughout.

The rapid advances in electronic techniques, particularly in relation to radar, made it essential to increase the accuracy of the time service. This was not an easy task, especially under the difficult war-time conditions, but a tremendous advance was made. The standard pendulum clocks were replaced by quartz clocks, mechanical measuring equipment was superseded by electronic devices capable of measuring time intervals in units of one-hundred-thousandths of a second, and new and improved methods were employed throughout. Since the war, many scientists and astronomers from observatories abroad have visited the station at Abinger to see the equipment and learn about the methods employed. Equipment developed by British firms in cooperation with the Observatory staff for use in the Greenwich time service is now being supplied to many countries where the time service is still of pre-war standard, and totally inadequate to meet present day demands.

For the reception and precision measurements of foreign radio time signals and for the checking of British radio time signals, special aerials were erected on Wotton Common. It also became necessary to radiate standard frequency transmissions from the Abinger station in order to make the full accuracy of the Greenwich time system available

to the Post Office, British Broadcasting Corporation, and many service laboratories and commercial firms. An aerial for this purpose was erected in a field on the north side of the road past the Observatory. Plans are now under consideration for the replacement of this aerial by one requiring only one mast, and placed in a field at a greater distance from the road.

Greenwich Observatory occupies a unique position among the observatories of the world as it has been adopted as the standard from which all measures of time and longitude are reckoned. Recently the Australian Government wished to improve the precision of the time service maintained by the Observatory at Canberra. It was decided that the longitude of the Canberra Observatory was not known with sufficient accuracy, and a special series of comparisons with Greenwich was therefore arranged. In order to ensure good reception of the Australian short-wave time signals, an additional aerial was erected on Wotton Common. The new determination of longitude showed that the previously accepted figure for Canberra was about one tenth of a second in error, so that the program was fully justified.

### Removal from Abinger

The work of the Magnetic Department is now becoming of far great importance. The variations in the magnetic field of the earth have now been shown to correspond to various disturbances on the Sun, which are studied by the Solar Department of the Observatory, and also to radio phenomena which are of direct interest to radio transmission engineers. The theoretical study of the relation between solar, magnetic, and radio phenomena is of great scientific and practical interest, and precise timing of the Abinger magnetic records is required. Interest is particularly directed to the very small fluctuations which occur, and unfortunately, since the electrification of the Dorking-Holmwood section of the Southern Railway, the Abinger magnetic records have been seriously affected by interference. Plans were already under consideration before the war for the removal of the magnetic work to a site more remote from possible sources of interference, and it is now hoped that the work will be transferred within the next few years.

Although the time station at Abinger has served well throughout the war period, and is still the main station for the control of radio time signals, it was never intended as a permanent site, and it is not, in fact, the most suitable. The whole Observatory is, however, in course of moving from Greenwich to Herstmonceux in Sussex. When the Observatory was established by Charles II over 250 years ago, Greenwich was in the country. London has grown, and the Observatory is now surrounded by smoke and grime, and the blaze of street lamps and flashing signs makes a glow in the night sky which is fatal to delicate astronomical photography. Many departments of the Observatory where work has become well-nigh impossible under present conditions are already being moved to Herstmonceux, and a new observatory instru-

ment designed for time observations is expected to be installed at Herstmonceux within the next two or three years. For the present, however, the "six pips" on the wireless will continue to come from Abinger, and the Post Office Talking Clock will receive its regular correction signals from the Observatory station on Leith Hill.

# Some Aspects of Evolution in Sun-Spot Cycles

By H. B. RUMRILL

The day-by-day watcher of sun-spots becomes impressed not only with their individual mutability but with the constancy of group changes, the members of which are in a state of continual commotion. Mentioned in Young's great work on the Sun as among unpredictable phenomena, the simile might be extended to the groupings of large and small spots and their interrelationships, also to the variations that are part of the eleven-year cycle.

It is the progressive rise and fall in the number of spots and groups throughout the cycles that brings the Sun into the category of slightly and irregularly variable stars, and which may be regarded as analogous to the pulsations of the Cepheid variables as characteristic of many densely gaseous bodies.

Assuming that nearly all stars are suns more or less like our own and that those which are self-luminous are necessarily of gaseous constitution, in varying degrees, with the differences shown by the spectroscope attributable to the manifold elements of which they are composed, the causes of variability arise from other physical conditions largely unknown.

Recognizing that solar variability reflects the gradual changes of spot formation and area in their entirety, even though at most a relatively inconsiderable proportion of the total surface—seldom so much as one per cent—its existence as an essential fact, possibly due to the phenomena of pulsation, lends additional interest to the study of spot diagrams formed by reduction from the Wolf relative numbers. These may be taken in daily averages (by number of observing days) of monthly totals as sufficiently representative of increase and decrease during consecutive periods of a cycle, but the following figures for the upwards of three years selected need no graph to serve as an exhibit of both variability and pulsation.

| | Number of Observing Days | Daily Average of Wolf Relative Numbers (coefficient 1 for 3-inch telescope; ¾ for 4-inch) |
|---|---|---|
| 1946 | | |
| July | 30 | 57 |
| August | 29 | 65 |
| September | 26 | 66 |
| October | 27 | 64 |
| November | 24 | 83 |
| December | 25 | 64 |
| 1947 | | |
| January | 19 | 71 |
| February | 24 | 76 |
| March | 28 | 84 |
| April | 24 | 83 |
| May | 26 | 127 |
| June | 25 | 93 |
| July | 28 | 88 |
| August | 25 | 122 |
| September | 25 | 107 |
| October | 27 | 110 |
| November | 22 | 85 |
| December | 19 | 81 |
| 1948 | | |
| January | 18 | 55 |
| February | 22 | 51 |
| March | 22 | 50 |
| April | 22 | 110 |
| May | 21 | 99 |
| June | 24 | 105 |
| July | 25 | 91 |
| August | 26 | 105 |
| September | 27 | 84 |
| October | 19 | 84 |
| November | 21 | 63 |
| December | 20 | 76 |
| 1949 | | |
| January | 14 | 68 |
| February | 21 | 102 |
| March | 23 | 104 |
| April | 24 | 82 |
| May | 26 | 70 |
| June | 26 | 67 |
| July | 27 | 74 |
| August | 26 | 78 |

The adequacy of comparisons by means of the Wolf relative sunspot numbers, in order to represent, with some degree of accuracy, the performance of telescopes of apertures not widely different, rests on the choice of appropriate coefficients based on the number one for a three-inch instrument, as fixed upon by the originator of the method.

Taking for granted the equivalence of defining and separating powers as between a 3-inch object glass and one of 4 inches reduced to the smaller aperture by a diaphragm stop (with similar magnification), if the lens curvatures in each case are perfect there should be no theoretical difference, the light admittance being alike. Practically, however, they are not precisely equivalent, due in part doubtless to the effect of different focal lengths and probably to variants in material, optical formulae, and workmanship. In my own experience with object glasses of those sizes, I have found an excellent 3-inch aperture not equal to a 4-inch in the matter of delicate detail; yet with the latter "stopped down" to 3 inches there was little noticeable deficiency versus full aperture.

In reducing the relative numbers resulting from the rule of number of groups (or isolated spots) multiplied by ten, plus the number of spots as determined with 4-inch aperture, by applying to the total an arbitrary coefficient of ¾ to represent the capacity of a 3-inch object glass, it would appear that the relationship between the two is approximately consistent, allowing for personal equation, although a minor element.

During the first half of the year 1944 the spot cycle dropped to

minimum, with the usual gradual recovery beginning definitely late in the summer. No spots were visible on 183 observing days in 1944, but there were scattered exhibits which increased during the autumn.

The upward surge toward steady activity continued through the years 1945 and 1946, reaching maximum in the following year. Then came a slight recession in 1948, with but a single day (March 22) having no spots recorded. In the secondary maximum of the cycle the highest number of spots counted was on May 11 of that year—145 in eleven groups—the seeing exquisite.

It must not be overlooked that in spot counting it is impossible to disregard the effect of the atmospheric conditions that make up the totality of seeing; thus, on the following day, May 12, the definition poor, but 67 spots could be recorded in the same number of groups; yet on the 15th, with good definition, only 47 spots were counted in twelve groups, and it is remarkable that the spots could have actually decreased in number so rapidly within such a short period.

Using the Wolf numbers as truly indicative of spot activity, my record for selected dates is as follows:

| | ——Number of—— | | Wolf Relative Numbers with coefficient ¾ for 4-inch telescope. (* indicates 3-inch telescope.) |
|---|---|---|---|
| | Groups | Spots | |
| 1945 | | | |
| September 20 | 1 | 2 | 9 |
| October 3 | 4 | 29 | 52 |
| November 15 | 6 | 13 | 53 |
| December 3 | 1 | 10 | 15 |
| 1946 | | | |
| January 16 | 6 | 35 | 71 |
| June 23 | 9 | 29 | 89 |
| July 30 | 5 | 79 | 97 |
| September 1 | 7 | 62 | 99 |
| October 23 | 10 | 39 | 104 |
| November 19 | 12 | 33 | 115 |
| December 26 | 7 | 63 | 100 |
| 1947 | | | |
| January 17 | 12 | 54 | 130 |
| March 7 | 7 | 98 | 126 |
| April 6 | 6 | 105 | 124 |
| May 23 | 13 | 129 | 194 |
| July 13 | 12 | 44 | 123 |
| August 13 | 16 | 120 | 210 |
| September 7 | 11 | 83 | 145 |
| October 3 | 11 | 112 | 166 |
| December 20 | 9 | 26 | 87 |
| 1948 | | | |
| February 1 | 1 | 4 | *14 |
| February 19 | 6 | 37 | 74 |
| March 29 | 8 | 31 | 83 |
| April 22 | 9 | 71 | 121 |
| May 11 | 11 | 145 | 191 |
| May 15 | 12 | 47 | 125 |
| June 6 | 10 | 42 | 106 |
| June 25 | 12 | 100 | 165 |
| July 30 | 10 | 61 | 121 |

| | ——Number of—— Groups | Spots | Wolf Relative Numbers with coefficient ¾ for 4-inch telescope. (* indicates 3-inch telescope.) |
|---|---|---|---|
| August 18 | 15 | 56 | 154 |
| September 14 | 9 | 45 | 101 |
| October 14 | 15 | 72 | 166 |
| November 14 | 6 | 13 | 55 |
| December 7 1949 | 9 | 30 | 90 |
| January 11 | 9 | 29 | 90 |
| February 5 | 9 | 101 | 143 |
| March 14 | 16 | 32 | 144 |
| April 21 | 8 | 71 | 113 |
| May 5 | 8 | 57 | 103 |
| June 29 | 11 | 56 | 125 |
| July 26 | 13 | 53 | 137 |
| August 22 | 12 | 58 | 133 |

Also of importance in its bearing from a statistical standpoint, as affecting a true picture of solar activity, is the counting of spots as such, regardless of their magnitude. To illustrate, in the great group of February 5, 1949, out of a total of 41 spots, large and small, there were twenty exceedingly minute spots, or half that number, that collectively might have about equalled in area the largest spot of the group. Yet, in any statistical process of dealing with groups of spots it would be difficult, not to say impossible, to reconcile comparative results better than the Wolf formula permits, so that, taken in connection with definition and other factors, it is not essentially at fault in affording a satisfactory index of spot development as a whole.

The dimensions of the group referred to above were approximately 27,000 x 108,000 miles, or an area of about three billion square miles —not unusual in these major disturbances.

Occasionally the spot groups assume some peculiarity of formation as in the massive Pleiades-like cluster of closely knit spots seen best on October 12, 1948. But the impression thus gained is often too evanescent to represent any great length of time, the continual round of change, frequently rapid, altering their appearance as with the clouds of a summer day.

As visual phenomena the faculae are sometimes perplexing to observe. Commonly more in evidence at or near the limbs, they are frequently seen much within those limitations, but with decreasing definiteness with distance from the circumference. Not having the well-marked formations characteristic of the spot groups, their visibility is somewhat influenced by the nature of the absorption glass attached to the eyepiece, certain colors producing better contrasts. For this sort of study I have found a Zeiss sliding wedge of "London Smoke" verging on green, compensated with clear glass, superior to some neutral screens tried, although so much depends upon atmospheric conditions that it is not easy to arrive at a positive conclusion in the matter. However, the faculae may not be reckoned statistically with the certainty

of the spot groupings, their importance resting on association with the latter as evidence of sub-surface activity (pulsation?), and generally as precursors of spot formation.

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# The Requirements for a Graduate Student at an Observatory

By OTTO STRUVE

*The Teachers' Committee of the American Astronomical Society feels that occasionally the points of view presented in the Teachers' Symposia should have the widest possible circulation. At our request, Dr. Struve permits the publication of the manuscript notes upon which he based his discussion which opened the Symposium at the December, 1948, meeting of the Society.*

FREEMAN D. MILLER, *Chairman*

This symposium was organized by Professor J. A. Hynek of Ohio State University. He wished to have someone present the case for an observatory and he asked me, in particular, to tell the teachers of astronomy in the United States what sort of training students should have before they go to do graduate work at an observatory. He added "I know that when I first entered Yerkes I was struck by the great difference in Continental undergraduate training and American undergraduate training." Hence he felt that it would be valuable to describe what sort of minimum background a student should have before he can successfully conduct his work at a large observatory.

Dr. Hynek has undoubtedly pointed out a difference which must be recognized and with which I hope our astronomical teachers will successfully cope. We have had at the Yerkes Observatory a great many students from American colleges and universities and we have also had a few whose training had been mostly in Europe. Hence I can make a comparison between the two groups. Let me say immediately that I have never noticed that there is the slightest difference, on the average, between what might be described as the innate ability of a student coming from the United States or from Europe. Nor am I aware that there is any great difference in the attitude of a student in so far as it depends upon very early training, that is, in those acquired traits which have come to him in his home and his early school years. There are, however, very definite differences between the two groups in regard to their formal knowledge. At the European universities formal knowledge is stressed to a much greater extent than it is in the United States. Hence, a student from Europe is usually better equipped with a knowledge of advanced mathematics and advanced physics than are our own students. This, however, is compensated by the fact that our students

possess greater manual dexterity and are therefore better equipped to do those kinds of work that required the handling, building, and adjusting of instruments. Moreover, I believe I am not mistaken when I say that on the average American students have more initiative than have the students who come from Europe. This results, for example, in a greater desire to conduct research work than is customary among graduate students in Europe.

Some years ago Professor Frank Schlesinger of Yale University made the following comment: "The late Dr. De Sitter once remarked to me that American astronomers were, with a few conspicuous exceptions, a group of specialists; and he added with a smile that he did not know whether this was an element of weakness or of strength for the general progress of science." I believe that this point is very important. It would be incorrect to conclude that our graduate students are less successful than are students who have had their undergraduate training in Europe. But I do believe that most of the successful astronomers who have come from our own universities have, on the whole, become rather narrow specialists. I want to stress most emphatically that I do not mean to make generalizations. There are all kinds of students in the United States and they have produced all kinds of astronomers. Therefore, if we think not only of what we might describe as the mean values of certain characteristics, but also their spread, or let us say, probable errors, then I believe we must admit that we have in both groups of students the entire range of characteristics from zero to their maximum value. It is merely a difference of where the average value happens to be. The question might arise as to whether we are not quite well off as we are. One might say that since we have produced great astronomers and are continuing to produce them at an undiminished rate, why not leave well enough alone and let the Europeans take care of their own type of training and their own type of astronomy? However, I would rather like to see some kind of adjustment which would give us a greater proportion of well-rounded astronomers —astronomers who can cover not only a narrow branch of their science extremely well, but who have a very broad understanding of the subject as a whole. I think it would be desirable to accomplish this without losing our advantages. In other words, I would consider it a very grave loss if we should be compelled to substitute broad general training for such skill and manual dexterity, initiative, or an ability to cope with specialized problems. Our educational system is a flexible one and a broad one. Perhaps we can accommodate within it both types of training. I do not wish to say that we should cram the brain of a poor undergraduate full of all kinds of information and expect him then to develop such things as manual dexterity in addition. I think teachers must always remember that after all the human brain has its limitations, and that no matter how well a program is designed its success is limited

not by the teacher, but mostly by the capacity of the student to absorb what he is given.

I realize that the diversity in training which I am advocating brings with it certain difficulties. Even now we find it quite disturbing that different colleges and universities have such a wide distribution of requirements among their undergraduate students. For example, we sometimes get students who have a very good background in mathematics and can easily follow a course by Chandrasekhar on the internal constitution of the stars. On the other hand, we also get students who know very little about mathematics. For example, we have had some who knew almost nothing about differential equations. Such students find it difficult, even from the very beginning, to follow a course of lectures in theoretical astrophysics. Hence, one possible improvement would be to standardize only the *minimum* requirements for entering graduate work at an observatory. I cannot do so offhand, but I would say that the student must have a very thorough knowledge of ordinary differential equations, and of course he must be entirely familiar with the more elementary aspects of analysis. In the field of physics, he must have a very good general knowledge of atomic theory, including the more recent advances in quantum mechanics, optics, thermodynamics, and electromagnetic theory. At the Yerkes Observatory we have found it necessary to give special courses in atomic theory. These courses deal with a subject that constitutes a part of physics and should not properly be given at an observatory, but here again we encounter so many cases where students have only the slightest knowledge of atomic physics that it is necessary for us to give them the fundamentals. So my first recommendation would be the preparation of a set of minimum requirements for a student to enter graduate study. I would prefer not to make this set of requirements too difficult, because, as I stated before, I believe that we would gain if we would introduce a certain diversity among our students. However, I would also advocate a plan whereby some of our graduate institutions would specialize more in the type of graduate study that is given in European universities, while others would continue in training students who are experimentalists. One might ask why such a division. Could it not all be done at the same institution? My answer is that to a certain extent we are already doing this, but the results are not altogether satisfactory. For example, at the Yerkes Observatory, we instituted some years ago a series of courses of formal lectures. On the whole they have enabled graduate students to get a very satisfactory amount of formal knowledge. It is difficult for us to vary our standards in accordance with the special interests of the students. Quite often we find that we get a student who does not have much interest in formal training but who is exceptionally well qualified for doing observational work with instruments and who is by no means necessarily stupid. On the contrary, a man of this type may be just as valuable and just as deserving

of a Ph.D. degree as one who takes an interest in the study of stellar constitution and handles his differential equations with the same ease with which the other student handles his photoelectric cells.

I suppose that other observatories have encountered this same difficulty. It is almost impossible in one institution to say that one student should take a certain course of lectures, while another student would be excused and would be expected to put together, let us say, an amplifier for a photoelectric photometer. But it seems to me that it could be done if different universities could get together and, more or less, divide the field among them. That is not now being done. I have never heard of graduate institutions in astronomy getting together and discussing their respective requirements. On the contrary, I think there is quite a bit of jealousy between them which results in a tendency to duplicate the work and eliminate diversity.

I would like to call attention to one other aspect of the situation which has been discussed at previous meetings of the Teachers' conference, but which I think should be stressed again and again. That is the lack of satisfactory textbooks. As we all know, there are on the market several very fine elementary textbooks in astronomy. There is no question that we in America have the best textbooks in the world in that particular field, but there is also very little question that we are among the least developed in regard to more advanced textbooks. It is a pleasure to know that this difficulty is likely to be removed, at least in part, with the appearance of a textbook by Dr. Aller. But I believe that this is not the only requirement. I think that we need additional textbooks of different levels so as to enable students to acquire a library of textbooks in different fields of astronomy, which are not too difficult for him. I want again to call attention to the policy of the Soviet Union in this respect. I have received occasional books from that country and I have been impressed with the enormous amount of publication of books of this type which the government has undertaken. You may have noticed that in a recent issue of the *Russian Astronomical Journal* there occur a great number of references to a textbook on astrophysics by Ambartzumian which was published in 1939. This book has never come to the United States—at least I have never seen a copy of it. Nevertheless it is quite obvious from the references to it that are now appearing in the literature that it has had a tremendous influence upon the development of astrophysics in Russia. There are other books which are of equal value. There is, for example, the textbook on Variable Stars by Kukarkin and the extension of his book on eclipsing variables by Martynov. There is also a new book by Parenago entitled "A Textbook of Stellar Astronomy." This is a volume of more than 400 pages dealing with problems of galactic structure and galactic dynamics. There is nothing of the sort now in existence in the English language except the brilliant but highly advanced monographs by Chandrasekhar. The volume is considerably more complete than, for

example, the textbook of Smart which was published in England. Now it is quite clear that students who have at their disposal a selection of textbooks of this kind have an enormous advantage over students who have hardly any textbook beyond the level of Russell, Dugan, and Stewart. I cannot solve this problem and I cannot suggest a practical solution for you. It is intimately connected with the fact that the sale of textbooks in this country would not bring in the kind of profit a publisher might desire, but I do think that it is necessary for us to keep stressing the fact that textbooks are absolutely necessary. Perhaps we should bring the matter to the attention of the National Research Council and ask the Council to form a committee to deal with this question on a national level, perhaps including other sciences. But there again, the question may be entirely different in the field of physics where large numbers of students are available and the publishers would not be averse to the publication of even fairly advanced textbooks.

YERKES AND MCDONALD OBSERVATORIES.

# The Teaching of Astronomy

The dissemination of astronomical lore is receiving more and more attention by school authorities. This situation is brought about, no doubt, by the publicity recently given to the installation of the very large reflecting telescope on Palomar Mountain in California. Dr. George Eby of the Department of Astronomy of the Stockton Junior College, Stockton, California, has sent a description of a method adopted by him in his teaching of astronomy, which he characterizes as inspirational readings. The following is typical of such readings which are given at the beginning of the class period, either by having them read or by using a tape recording.

ARE WE ALONE?

Do we have living neighbors in the sky? Are the planets inhabited? Who will answer these questions? Must we wait for the development of rockets to Mars or can science give us a satisfactory answer today? Yes, science can give us an answer, but it may *not be satisfactory* to us.

Science attacks the problem in this manner: Life, as we know it, could exist on the planets only when their climates and living conditions are similar to ours. But, are living conditions on the rest of the sun's family similar to those on earth? First, let us turn our eyes to Venus, that beautiful evening star which shines above all the rest.

Venus is almost as big as the earth and, being a little closer to the sun, it ought to have a nice balmy climate without the frozen winters we have in the northland. Its days are believed to be about as long as 15 of ours and its nights equally extended. Fifteen days

without rest would tax our strength, to be sure, and fifteen nights in a row would give us more sleep than we need, but this factor alone would not preclude the possibility of life on Venus. So let us visit this beautiful planet and get acquainted with its inhabitants. But wait a moment! Be careful! You will die if you go to Venus. There is no oxygen in the atmosphere of Venus—you will suffocate. There is no water on Venus—you will die of thirst. Venus is a barren desert where rain never falls. There are no sparkling brooks which trickle down the hillsides into the sea.

What more do we know about the atmosphere of Venus? We know this: Venus has over 10,000 times as much carbon dioxide as we have. How does this affect its climate? Carbon dioxide is such a good blanket or insulator that it can hold the heat of the sun until the surface of Venus is hotter than boiling water. No life, as we understand it, can live in a region devoid of water and oxygen, where the land scorches under a temperature higher than the boiling point. Put Venus back into the evening sky and be content with its scintillating beauty. There is no life there—as we know it.

Let us hurry on to Jupiter, the largest planet of all. Before we ask, "Is there life on Jupiter?" let us study its climate. Jupiter like Venus has neither oxygen nor water in its atmosphere. Instead, the air is charged with choking ammonia fumes. The temperature is over 100 degrees below zero. The land is perpetually covered with a solid layer of ice, 17,000 miles thick. Need we go further? There is no life there as we understand it.

Shall we go to Saturn, that beautiful ringed planet which floats so quietly along, far out in the depths of our night. There is no use. Saturn is so far from the sun, that it will receive less heat in three months than we will get in one day. Saturn is a frozen planet with a temperature 300 degrees below zero. There is no oxygen. No water. Just methane and ammonia falling as snow.—There is no life there as we know it.

Then are we alone? Cut adrift in space to whirl endlessly around the sun, never to expect visitors from our neighboring planets. But wait! We have one more planet to explore. Mars, the red god of war which floats just outside our earthly boundary. Is the climate on Mars suitable for life as we know it? Mars is about half as big as the earth. Therefore its gravity cannot hold as dense an atmosphere as we can. Yes, Mars has oxygen, but it is thinner than over Mt. Everest. Mars has water too. But it has less than 5 per cent as much water as we have. This might be enough moisture for an occasional rain, but most of Mars is likely to be a desert. Not a hot desert like on Venus and Mercury, but a cold desert where the temperature drops 100 degrees below zero each night and then reluctantly rises above freezing at noon in the

tropics. Yes, life on Mars *is* possible. But the climate is so severe, the air so thin and dry that it is difficult to believe that life as we know it could be maintained on such a planet.

Has Mars always been a desolate waste from the day it cooled into a solid globe? Some astronomers do not think so. One reason they built the 200-inch telescope was to try to find out whether Mars has ever been inhabited. It is possible that Mars started out with plenty of oxygen and water only to lose it through excessive oxidation and dissipation. Millions of years ago, some believe, Mars could have had a climate similar to ours. Is there any visible evidence that intelligent beings have ever lived on Mars? Some astronomers believe the so-called canals are evidence enough. If they can ever get photographic evidence to prove the canals really exist, as astronomers have drawn them, they believe this will be undeniable proof of life having once been on Mars. Drawings of these canals show three things which could not be explained on the basis of accidents. First, they appear to be straight lines over 3,000 miles in length; second, many diverting canals lead off at right angles; and third, they follow great circle routes. Why would these three items prove the existence of intelligent beings? The answer is that straight lines are practically unknown in nature, especially 3,000 miles in length. Furthermore, right angles are very rare on this earth unless they are man made and lastly, geographical disturbances which follow great circle routes are completely unknown. Consequently, a combination of all three of these unique features would be looked upon as mathematically impossible in nature and could only be explained as the work of intelligent beings.

Thus, if these canals really exist, they were evidently built millions of years ago to bring Mars' diminishing water supply from the polar ice caps into the tropics. In this manner it might have been possible to perpetuate life for thousands of years beyond the time when all major forms of life would have died for lack of water and oxygen. Thus it may be that Mars is now but a giant tombstone commemorating the existence of life which once existed on another planet.

We are alone. We are the last remnant of life which belongs to our sun. Will we in turn build canals and other ingenious devices to prolong life on the earth for aeons after the climate no longer stimulates life in abundance? Or will we, just in our prime of existence, destroy ourselves with atomic bombs and radio active clouds? The next time you step out into the darkness, look up at Mars, the god of war, and ask yourself, "Did the Martians waste their dwindling resources in endless wars? Did they perfect the atomic bomb a million years before we ever heard of it? Or did they harness the atom and put it to building canals in order that life might continue for ages hence?"

# On the Photometry and Colorimetry of Close Double Stars*

By PAUL MULLER

In 1946 I mentioned[1] my intention of measuring double stars photometrically with a new type of micrometer. I have since been able to secure some 1600 measures of $\Delta m$, the difference in magnitude between the components of more than 200 double stars. Based on this experience the following report can now be made about the results and about the precision of the method and its limitations. The observations include:

1. 430 measures[2] on 70 pairs, distances ranging from 2″ to 10″, with the 16 cm. refractor of the Strasbourg Observatory.
2. 650 measures on 130 pairs, distances ranging from 0″.6 to 3″ with the 49 cm. refractor of the Strasbourg Observatory.
3. 64 measures on 27 pairs, distances ranging from 0″.45 to 1″.2 obtained during a short stay at the Pic-du-Midi.

Also, the $\Delta m$ of some 40 objects among the brighter of the two first lists have been measured in two colors defined by the Wratten filters 24 (red) and 64 (green-blue). The double-refracting prism mounted on the micrometer allows measures to distances up to 12″ with the smaller telescope and up to 3″ with the larger one. A somewhat larger prism for use with the larger telescope will extend the limit to 3″.7. The restriction of this upper limit is not very serious in view of the possibilities of the photographic method for larger separation.[3]

The domain covered by our measures is largely unexplored. In the case of measures without filter previous investigators do not go below 2″. The only measures of closer pairs are those by Kuiper and refer to stars brighter than $6^m.5$. This large piece of work undertaken in 1930 has not been published. Only a few results have been mentioned incidentally. Of the 130 pairs in the second group listed above only 34 pairs have been measured previously and that with less precision. I measured $\Delta m$ the first time in the following well-known pairs: Σ 3062, Σ 73, $\eta$ Gem, $\zeta$ Can, $\phi$ UMa, and $\zeta$ Boo.

It is inherent in the method of measuring that the limit of magnitude depends on the $\Delta m$ itself. The case of nearly equal magnitudes is the least favorable. It is well known that in the published catalogues the fainter companion of a bright star is estimated systematically too faint.

At Strasbourg we are limited to 8th magnitude for equal pairs while we go beyond 9th magnitude when the companion is faint. The mean error of the first series is $0^m.04$ and $0^m.06$ in the second. The method is therefore far superior to previous determinations.

*From a note to the French Academy. This amplifies the remarks at the end of Wallenquist's article on the same subject in the January issue, p. 19 (1949). G.V.B.

In regard to heterochrome measures our data are largely the original ones since to our knowledge such results have been obtained only in a small number of special cases: Sirius by M. Danjon in *Journal des Observateurs,* **19**, 200 (1936) and $\gamma$ And by Pickering and others in *Harvard Annals,* **2**, (1879). Our measures give the difference in color index of the two components of a pair. In most cases the integrated spectrum is known when the $\Delta m$ is small or the spectrum of only the principal star when $\Delta m$ is large. In the first case our measures give the two indices, in the second the color index of the companion only. From pairs in which both components have known spectra I have found that our method gives a precision of $0^m.1$ in the color index, corresponding to two or three tenths of a spectral class. Since the filters do not affect the smaller distances this makes an interesting extension of the domain so far explored by the spectroscope.

REFERENCES

[1] *Comptes Rendus,* **223**, 20 (1946).
[2] *Ann. Obs. Strasb.,* **5**, part 1 (1948).
[3] J. G. Ferwerda and C. J. Kooreman, *B. A. N.,* **10**, 169 (1946).

## The Planets in November, 1949

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

*Sun.* The sun continues its rapid southerly retreat during this month, so that by the end it will be nearly 22 degrees south of the equator.

*Moon.* The phases of the moon will occur as follows:

| | | | |
|---|---|---|---|
| Full Moon | November | 5 | 3 P.M. |
| Last Quarter | | 13 | 10 A.M. |
| New Moon | | 20 | 1 A.M. |
| First Quarter | | 27 | 4 A.M. |

The moon will be nearest to the earth on November 19.

An occultation of Saturn on November 15 is described under the notes on that planet.

*Evening and Morning Stars.* Jupiter and Venus will be visible in the early evening; while Saturn and Mars will also appear close together in the morning sky.

*Mercury.* Since it passes superior conjunction on November 21, Mercury will be practically unobservable during this month.

*Venus.* On November 20 Venus will stand at its maximum elongation of 47¼ degrees east of the sun. However, the conspicuousness expected to accompany this aspect will be largely curtailed for northern observers by the simultaneous location of the planet at nearly 27 degrees south declination. This is almost an extreme declination for naked-eye planets. However, the moon will pass almost 2 degrees south of Venus on November 23.

*Mars.* Mars will be moving eastward in Leo between Regulus and Saturn, and will appear similar to those objects except for its redder color. It will overtake and pass to the north of Saturn on November 30. So close will be the conjunction that, on the morning of that date, the two planets will be difficult to separate with the unaided eye.

*Jupiter.* During the close association with Venus in the southwest twilight the brightness of Jupiter will suffer by comparison, since Jupiter will be more than two magnitudes fainter than Venus. However, Jupiter's position to the northeast of Venus will give it a more favorable altitude.

*Saturn.* Now two months past conjunction with the sun, Saturn will be rising before 3 A.M. in the morning sky. Its remarkable association with Mars is described under notes on the latter planet. Still more remarkable, perhaps, will be its occultation by the moon which will be visible from the northeastern quarter of the United States on November 15. Since the immersion will occur after 7:15 A.M., the sun will be up, and, therefore, a small telescope will be required to observe the occultation.

*Uranus.* Uranus will be moving very slowly westward at about a degree north of $\mu$ Geminorum.

*Neptune.* Neptune will be moving south-southeastward at about a degree west of $\theta$ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.,
September 7, 1949.

## Asteroid Notes

By HUGH S. RICE

There seems to have been unusual activity in observation of the asteroid VESTA during the last summer. Various reports of successful observations with field-glasses and small telescopes have been received, as for example from Weitzenhoffer and Oravec in New York, O'Toole and associates in Vallejo, California, and Spears at Binghamton, N. Y. Spears made many observations and in June estimated the visual magnitude to VESTA as 5.7, using B. D. comparison stars. This is exceptionally bright, even for this planet, the brightest of all of them. Another notable point is that the asteroid did not follow the published ephemeris exactly, and this has been reported by several observers. VESTA's orbit is so well known that this situation is surprising.

30 URANIA. This asteroid was discovered in 1854 by Hind at London; it was then of magnitude 9.5. The opposition this year is on October 15. During our period of observation the magnitude is about 9, and its apparent path extends from a point 2° south of Eta Piscium on October 5, to a point 3° north and 1° west of Epsilon Piscium on November 20. The last two positions have been extrapolated by us, for the ephemeris as given by the computers does not quite fit the period covered by this issue. About 1½° east of Eta Piscium, the key star, is a Messier object (M 74, NGC 628) described by J. Herschel as a very large, giant star cluster. It is however a spiral galaxy, and was called a spiral by Lord Rosse.

9 METIS moves westwardly along the edge of Aries just north of the Pisces border. On the evening of November 3 it passes north of Mu Ceti by ½°. Opposition is on November 5, and the magnitude of the planet is 8. 57 MNEMOSYNE is at first close to METIS but soon takes a course across the head of the Whale.

Opposition is November 5, and the magnitude 10. 679 PAX is in eastern Eridanus, with opposition December 3 and magnitude 9.

The following 15 minor planets are the brightest to be seen in 1950.

BRIGHT ASTEROIDS FOR 1950

| PLANET | OPPOSITION | MAGNITUDE | PLANET | OPPOSITION | MAGNITUDE |
|---|---|---|---|---|---|
| 3 Juno | March | 9 | 7 Iris | July | 9 |
| 5 Astraea | March | 9 | 15 Eunomia | July | 8½ |
| 532 Herculina | March | 9 | 39 Laetitia | September | 9 |
| 2 Pallas | May | 8 | 27 Euterpe | October | 9 |
| 11 Parthenope | June | 9 | 4 Vesta | November | 7 |
| 1 Ceres | June | 7½ | 18 Melpomene | November | 8 |
| 10 Hygiea | June | 9 | 29 Amphitrite | December | 9 |
| | | | 6 Hebe | December | 8 |

ASTEROID EPHEMERIDES

For $0^h$ U.T. Equinox 1950

| 1949 | 30 URANIA α h m | δ ° ′ | 1949 | 9 METIS α h m | δ ° ′ |
|---|---|---|---|---|---|
| Oct. 3 | 1 30.0 | +13 27 | Oct. 19 | 2 58.0 | +11 1 |
| 11 | 1 22.9 | +12 53 | 27 | 2 50.8 | +10 47 |
| 19 | 1 15.4 | +12 12 | Nov. 4 | 2 42.7 | +10 33 |
| 27 | 1 8.3 | +11 29 | 12 | 2 34.4 | +10 23 |
| Nov. 4 | 1 2.4 | +10 49 | 20 | 2 26.8 | +10 19 |
| 12 | 0 58.5 | +10 17 | 28 | 2 20.5 | +10 22 |
| 20 | 0 57.4 | + 9 58 | Dec. 6 | 2 16.2 | +10 31 |

| 1949 | 57 MNEMOSYNE α h m | δ ° ′ | 1949 | 679 PAX α h m | δ ° ′ |
|---|---|---|---|---|---|
| Oct. 19 | 2 55.1 | + 9 8 | Nov. 12 | 5 1.8 | −15 28 |
| 27 | 2 49.9 | + 7 58 | 20 | 4 55.4 | −14 43 |
| Nov. 4 | 2 44.2 | + 6 49 | 28 | 4 46.6 | −13 22 |
| 12 | 2 38.5 | + 5 44 | Dec. 6 | 4 37.4 | −11 31 |
| 20 | 2 33.2 | + 9 48 | 14 | 4 29.0 | − 9 14 |
| 28 | 2 28.6 | + 4 3 | 22 | 4 21.9 | − 6 37 |

Hayden Planetarium, American Museum of Natural History, New York, September 21, 1949.

## Occultation Predictions for November, 1949

(Taken from the *American Ephemeris*)

| Date 1949 | Star | Mag. | IMMERSION Greenwich C.T. h m | IMMERSION a m | IMMERSION b m | IMMERSION Angle E from N ° | EMERSION Greenwich C.T. h m | EMERSION a m | EMERSION b m | EMERSION Angle E from N ° |
|---|---|---|---|---|---|---|---|---|---|---|
| OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′ | | | | | | | | | | |
| Nov. 7 | 104 B.Taur | 5.5 | 5 9.8 | −1.6 | +1.7 | 54 | 6 35.8 | −2.1 | 0.0 | 259 |
| 9 | 107 B.Auri | 6.5 | 4 49.2 | −2.4 | −0.9 | 127 | 5 42.4 | −0.9 | +4.1 | 207 |
| 10 | 49 Auri | 5.0 | 5 56.5 | −1.8 | +0.2 | 107 | 7 17.3 | −2.0 | +1.4 | 250 |
| 10 | 54 Auri | 5.8 | 8 51.4 | −2.6 | +3.2 | 41 | 9 37.8 | .... | .... | 336 |
| 10 | 25 Gemi | 6.5 | 9 56.4 | −2.8 | +2.4 | 42 | 10 38.6 | .. | .. | 340 |
| 12 | 28 Canc | 6.1 | 5 42.3 | −0.3 | +3.3 | 51 | 6 28.4 | −1.6 | −1.8 | 331 |
| 15 | SATURN | 1.2 | 13 29.7 | −1.2 | −1.6 | 134 | 14 41.7 | −1.1 | −1.7 | 305 |
| 25 | 33 Capr | 5.5 | 22 23.6 | −2.6 | −0.7 | 103 | 23 20.9 | −0.2 | +1.4 | 193 |

| Date 1949 | Star | Mag. | IMMERSION Greenwich C.T. | *a* | *b* | Angle E from N | EMERSION Greenwich C.T. | *a* | *b* | Angle E from N |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | m | m | m | ° | h m | m | m | ° |
| **Occultations Visible in Longitude +91° 0′, Latitude +40° 0′** | | | | | | | | | | |
| Nov. 7 | 104 B.Taur | 5.5 | 4 42.4 | —0.6 | +2.8 | 31 | 5 53.8 | —2.4 | +0.3 | 272 |
| 9 | 107 B.Auri | 6.5 | 4 17.1 | —1.0 | +0.9 | 102 | 5 20.8 | —0.6 | +2.6 | 227 |
| 10 | 49 Auri | 5.0 | 5 28.2 | —1.0 | +1.1 | 93 | 6 42.4 | —1.3 | +1.7 | 254 |
| 10 | 54 Auri | 5.8 | 8 4.9 | —1.8 | +2.5 | 55 | 9 15.9 | —2.1 | —2.1 | 309 |
| 10 | 25 Gemi | 6.5 | 9 8.1 | —2.2 | +1.3 | 68 | 10 27.4 | —1.7 | —2.1 | 304 |
| 11 | $\nu$ Gemi | 4.2 | 7 30.0 | .. | .. | 36 | 8 10.9 | —2.2 | —3.6 | 336 |
| 12 | 28 Canc | 6.1 | 5 37.7 | +0.9 | +4.4 | 33 | 6 4.4 | —1.7 | —2.6 | 343 |
| 15 | Saturn | 1.2 | 13 19.7 | —0.2 | —3.0 | 177 | 14 12.0 | —2.7 | +0.1 | 263 |
| 25 | 33 Capr | 5.5 | 21 40.1 | —2.1 | +0.9 | 80 | 23 1.1 | —1.5 | +1.0 | 222 |
| **Occultations Visible in Longitude +98° 0′, Latitude +31° 0′** | | | | | | | | | | |
| Nov. 7 | 104 B.Taur | 5.5 | 4 14.7 | —0.5 | +2.4 | 40 | 5 30.5 | —2.1 | +1.2 | 259 |
| 9 | 107 B.Auri | 6.5 | 4 4.1 | —1.1 | +0.3 | 115 | 4 54.2 | +0.2 | +3.0 | 212 |
| 10 | 49 Auri | 5.0 | 5 13.8 | —1.0 | +0.4 | 109 | 6 16.9 | —0.6 | +2.4 | 233 |
| 10 | 54 Auri | 5.8 | 7 36.3 | —1.9 | +1.1 | 82 | 9 7.7 | —2.6 | +0.1 | 274 |
| 10 | 25 Gemi | 6.5 | 8 46.5 | —2.5 | —0.1 | 101 | 10 21.7 | —2.6 | 0.0 | 267 |
| 11 | $\nu$ Gemi | 4.2 | 6 57.8 | —0.8 | +1.9 | 67 | 8 10.0 | —2.1 | —0.5 | 298 |
| 12 | $\nu^1$ Canc | 5.7 | 6 36.5 | 0.0 | +2.3 | 58 | 7 28.9 | —1.5 | —1.1 | 319 |
| 12 | $\nu^2$ Canc | 6.4 | 7 29.2 | —0.1 | +4.4 | 40 | 8 5.6 | —2.1 | —3.6 | 341 |
| 15 | 308 B.Leon | 5.9 | 8 45.0 | .. | .. | 34 | 8 53.6 | .. | .. | 18 |
| **Occultations Visible in Longitude +120° 0′, Latitude +36° 0′** | | | | | | | | | | |
| Nov. 9 | 107 B.Auri | 6.5 | 4 4.4 | +0.3 | +1.4 | 69 | 5 1.8 | —0.2 | +1.3 | 262 |
| 9 | 406 B.Taur | 5.6 | 12 59.9 | —0.7 | —4.2 | 146 | 13 50.4 | —2.3 | +1.3 | 225 |
| 10 | 49 Auri | 5.0 | 5 14.3 | +0.4 | +1.6 | 63 | 6 11.1 | —0.6 | +0.9 | 281 |
| 10 | 54 Auri | 5.8 | 7 27.3 | +0.2 | +3.6 | 32 | 8 14.6 | —2.3 | —1.3 | 315 |
| 10 | 25 Gemi | 6.5 | 8 12.1 | —1.0 | +2.1 | 63 | 9 28.1 | —2.2 | —0.1 | 288 |
| 25 | 56 B.Capr | 6.3 | 3 23.0 | —0.4 | +0.5 | 38 | 4 25.3 | —0.8 | —1.0 | 265 |

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

# METEORS AND METEORITES

## Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The following article consists of three parts, each by a different person I am glad to say, as I am most happy to have others contribute to Meteor Notes. The first is the case of a fireball, seen from two ships, and the results are calculated by me. The second is the fireball of 1945 October 20/21, the results being calculated by T. A. Scott, working with me this summer. The third is an interesting article sent me by Professor Cuno Hoffmeister, the well-known German authority

on meteors. Incidentally, I hope to publish here soon a longer review of his important new book "Meteorströme," already briefly mentioned. Members of the A.M.S., seriously interested in the theoretical aspects of the subject, should secure a copy at once.

As for the two summer showers, the epoch of the Delta Aquarids was covered by a few of our observers, most particularly by a group at Wilson, N. C., under the guidance of E. A. Eason, our regional director. I expect to publish details of these reports when there has been time to work them up. Moonlight and bad weather combined in this part of the country to ruin the Perseids, so few results are anticipated on them this year. We do urge our observers to concentrate on the Orionids, Leonids, and Geminids as the Moon will be rather favorable for all of the three epochs.

Too many of our members seem totally inactive. If everyone would observe for say only once a month for a period of 3 hours or more beginning at 11:00 P.M. on a clear, moonless night, our annual total would more than double!

### Fireball of 1949 April 4/5

### A.M.S. No. 2316

This fireball was reported by two ships in the eastern Atlantic. The solution will be discussed in more detail than usual as an interesting special case is presented. The two reports appear in the *Hydrographic Bulletin*, U. S. Navy, and are quoted in abridged form.

S1. ". . . Sec. Off. G. Olsen . . . Am. S. S. Bowdoin Victory . . . April 4, 1949, at 2215 G.C.T. . . . lat. 39° 03′ N, long. 38° 14′ W., a large meteor was observed. When first seen it was traveling towards the ship on the bearing 115° at an altitude of about 45°; it appeared to be very close . . . disappeared at about 5° . . . bearing 115° . . . visible about 5 seconds . . . illuminating the whole sky ahead . . . very brilliant . . . mostly white with a tinge of light blue . . . the tail . . . very short . . . red with trailers of white. . ."

S2. "Chief Off. C. B. P. Bradbury and Third Off. J. C. Lister . . . Br. motorship City of Khartoum . . . April 4, 1949, at 2215 G.C.T. . . . lat. 37° 40′ N, long. 40° 20′ W, a meteor was observed bearing 85° . . . visible 4 to 5 seconds . . . first . . . ice-blue light at an altitude of about 10°, approaching the horizon at an angle of 10° from the vertical with a northward line of approach . . . four times size of Venus . . . at 7° . . . tremendous . . . flash . . . afterwards a great orange ball of fire . . . many orange fragments issuing and falling from it. These . . . fell below the horizon. . ."

The usual diagram was plotted with the ships' positions thereon, and then the bearings (*i.e.*, azimuths—180°) plotted. Where these cross one another are the sub-beginning and sub-end points. These two points, B and E, are then measured from S1 and S2, and, if the unit on map is 1′ in latitude, the curvature corrections for altitudes are $+S_1B_1/2$, $S_2B_2/2$, $S_1E_1/2$, and $S_2E_2/2$, respectively. Computations are carried out with 1′ as our unit of length; the data for publication are multiplied by 1.845 to turn these values into kilometers.

The two end heights came out 30.23 km and 15.08 km, respectively, mean $22.7 \pm 7.6$ km, which is fairly good. Incidentally this gives reason to believe that the object dropped meteorites, though naturally these will never be found. The beginning heights were, at first glance, hopelessly discordant, being 317 km and 99 km. However, fortunately the object fell vertically for S1 and only 10° off for S2. Also $B_1E_1$ is only 26 km on our diagram. From this we readily deduce a new height for S2 of 148 km, using the value of the slope. We weight 319

and 99 as 1:2, obtaining 172. We then weight 172 and 148 as 2:1, obtaining 164 km which we take as $E_1E$. The justification for the first is that generally 45° is a notoriously poor estimate while two men agreed on 10°, an angle far easier to estimate correctly. The value from the slope was then added in at half weight. Though this procedure may appear somewhat arbitrary, thanks to the nearly vertical path, no matter which of the values for $B_1B$ is adopted, it affects the radiant very little—a most fortunate circumstance and rather unusual.

In view of what has been said the beginning height, the length of path, and the observed velocity are subject to considerable uncertainty, whereas the end height and the radiant seem to be fairly well determined. The usual data follow.

| | |
|---|---|
| Date | 1949 April 4.93 G.C.T.; 1949 April 4.43 G.M.T. |
| Sidereal time at end point | 167° |
| Began over | $\lambda = 35°\ 06'$ W, $\phi = 37°\ 57'$ N, at 164 km |
| Ended over | $\lambda = 35°\ 21'$ W, $\phi = 38°\ 02'$ N at $23 \pm 8$ km |
| Length of path | 143 km |
| Projected length of path | 26 km |
| Duration | 4.75 sec |
| Velocity | 30 km/sec |
| Radiant (uncorrected) | $a = 296°$, $h = 81°.4$ |
| Zenith correction | inappreciable in this case |
| Radiant | $\alpha = 176°$, $\delta = +34°$ |
| A.M.S. No. | 2316 |

In the von Niessl-Hoffmeister catalogue this radiant might be compared with No. 532, which incidentally is so like No. 534 that a misprint is suspected.

Finally it may be remarked that errors in the estimated positions of the ships can be as harmful as errors in altitudes and bearings. It is hoped that ships' officers who report such phenomena keep this fact in mind.

### Fireball of October 20/21, 1945; A.M.S. No. 2317

*By* Thomas A. Scott

On this date at 2:59 A.M., E.S.T., a beautiful fireball was observed moving north 66 degrees east over the Atlantic Ocean at an average distance of 130 miles off shore by residents of Pennsylvania, New Jersey, Delaware, New York, and Connecticut. In spite of the unfavorable time for observation around thirty reports on the fireball were received here, thirteen of these with usable azimuths and altitudes. To all those who took the trouble to write in we express our most sincere thanks.

The usual A.M.S. graphic method was employed, a map made and the azimuths plotted. At first glance, solution did not look very promising; but by a long study and careful weighing of the data at hand we have results in which we have fair, though not strong confidence. A few reasonable approximations had to be made and, as is often true, one observation had to be made the key one for the solution; in this case that of Second Officer S. M. Thulkeld, from the American S. S. City of Bristol in lat. 38° 26′ N., long. 73° 37′ W. His observation seems to have been very carefully made and it placed the path almost exactly where I had decided it should be from the other data. Strangely enough he, however, omitted the time.

Estimates of the meteor's size vary from 1/10 the diameter of the Moon to 2 degrees diameter! Four observers place it at ½ the Moon and this seems to be the most nearly correct. The only estimate on magnitude comes from Edward Oravec at Yonkers, New York. He estimates it as —11 magnitude at the point

where it disappeared from his view. This point was about 300 kilometers from Yonkers and about 40 kilometers from the calculated end point of the fireball.

Color estimates, as usual, vary, but the preponderence of evidence is for a red center surrounded by a green or blue-green coma followed by a short orange tail.

Four persons report an explosion at the end. Three others report a very bright flash just after the fireball disappeared from their view behind buildings or trees. E. N. Langrish of Weathersfield, Connecticut, reports that it burst into three parts—one large, and two small. No one else reports seeing more than one body after the explosion. The fireball seems to have disappeared upon explosion or very soon thereafter. No sound phenomenon is reported. Indeed, the distance might well account for this.

Apparently no enduring train whatsoever was left by this very large fireball. However, from Mr. W. S. Shultz and Second Officer Arvid Karlson of the Woods Hole Oceanographic Institution came a most interesting report. They observed the fireball from the research ship, Atlantis, in lat. 39° 45′ N., long. 70° 55′ W., and were only about 55 kilometers north of the end point. No train was left that they report; but at 5:15 as dawn began to break a peculiar white trail having a vapor-like appearance was observed appearing slightly south of east about 15 degrees high. At 5:45 three black and white photographs were made and a short exposure taken with a 16 mm movie camera on kodachrome film. The trail disappeared as the Sun came above the horizon, probably due to the fact that being so near the Sun it was lost in the glare. The photographs were mailed here. They show an extremely curved and twisted white trail that somewhat resembles an interrogation point with a crooked line from the bottom toward the left as the point is written. This trail has every appearance of a spiral meteor train which has suffered long differential drift from wind currents in the upper atmosphere. The observers on the ship believed that it was connected with the fireball, but this connection cannot be proved, though admittedly the trail is difficult to explain on any other assumption. There is no way of finding the height and distance of this trail as we only have this one observation. It is however in the same direction in which the meteor was going. If this was a train left by the fireball it was inferentially not luminous within itself and appeared only when the sunlight was reflected from it. This seems improbable, but cannot be completely ruled out. Therefore, I feel justified in this full discussion of the phenomenon. Furthermore, no other fireball was observed from the ship though one of the party was on watch at all times.

Due to the uncertainties of the radiant no orbit was calculated. The usual data follow.

| | |
|---|---|
| Date | 1945 October 21.37 G.M.T. |
| Sidereal time at end point | 78° 14′ |
| Began over | lat. 38° 38′, long. 72° 40′ at 127 km |
| Ended over | lat. 39° 17′, long. 70° 55′ at 40 km |
| Length of Path | 188 km |
| Projected length of path | 166 km |
| Radiant (uncorrected) | $a = 66°$, $h = 28°$; $\alpha = 24°$, $\delta = +1°$ |

The radiant is A.M.S. No. 2317.

## A New Meteor Current and its Cometary Connections

*By* C. Hoffmeister, Sternwarte Sonneberg

In the year 1937-38 the author of this paper had the opportunity of observing meteors on the southern hemisphere under the most favorable conditions that

can be imagined. The place was situated near Windhoek in the Mandated Territory of Southwest Africa at 17° 5′ eastern longitude and 22° 35′ southern latitude, 1683 meters above sea level. More than 9000 paths have been plotted. The results have been published elsewhere in the meantime.[1]

One outstanding item of the results is the discovery of an as yet unknown meteor current, radiating late in June and early in July from the constellation Corvus. This current was first noticed on the evening of June 25, 1937, two days after Full Moon and obviously had its maximum on the following evening with a zenithal hourly rate of 13, then gradually declining and vanishing about July 2 or 3. The position of the radiant point has been derived as follows:

Solar longitude 95°.6, $\alpha = 191°.6$, $\delta = -19°.2$,
$\lambda\ 198°.4$, $\beta = -13°.0$. Equinox 1925.0

The epoch of maximum is probably 1937 June 27.0 at solar longitude 94°.9. The radiant was rather diffuse, forming an area of about 15° diameter.

The position of this radiant is mentioned neither in the catalogue of Denning nor in that of McIntosh, nor has it been detected by the observers of the Harvard Expedition to Arizona in 1931-32. For higher northern latitudes the radiant sets about the same time as the sun, but recent radar investigations also seem to have failed to show the existence of a current radiating from that center. There are strong indications that the current was of a temporary character.

As described at a previous occasion[2] a method had been developed to determine independently the orbits of meteor current, semi-major axis and eccentricity included. The application of this method to the Corvids immediately showed that the current most probably is to be ascribed to a comet of the Jupiter group, the semi-major axis being between 2.5 and 3.0 astr. units, probably very near the lower limit. Under this assumption the following two elliptical orbits have been computed:

| | | I | II |
|---|---|---|---|
| Time of perihelion passage | T | 1937 July 23.31 | 1937 July 3.25 |
| Argument of perihelion | $\omega$ | 38° 54′ | 7° 44′ |
| Ascending node | $\Omega$ | 274° 54′ | 274° 54′ |
| Inclination | i | 2° 32′ | 3° 6′ |
| | | 1937.0 | 1937.0 |
| Eccentricity | e | 0.6281 | 0.6624 |
| Semi-major axis | a | 2.5 | 3.0 |
| Perihelion distance | q | 0.9296 | 1.013 |
| Period of revolution | P | 3.953 years | 5.196 |

The search for a parental comet failed to yield any immediate result. But a rather striking resemblance to the orbit of Comet Tempel 3-Swift, except for argument of perihelion, was noticed. Indeed this discrepancy is so large that any connection should be excluded if there were not prevailing peculiar circumstances. The comet's orbit in the return of 1914 has been computed by Viljew as follows:

| | |
|---|---|
| T | 1914 July 21.285 meantime Paris |
| $\omega$ | 139° 34′.4 |
| $\Omega$ | 264° 23′.0 |
| i | 7° 8′.6 |
| | 1914.0 |
| e | 0.61861 |
| a | 3.240 |
| q | 1.2342 |
| P | 5.832 years |

But the orbit is very unstable owing to continuous perturbations by Jupiter. According to the computations by Ramensky the following changes of elements occurred from 1869 to 1938:

| | | | | |
|---|---|---|---|---|
| Argument of perihelion | from | 106°.2 | to | 161°.5 |
| Ascending node | from | 296°.8 | to | 241°.8 |
| Inclination | from | 5°.4 | to | 13°.3 |
| Perihelion distance | from | 1.064 | to | 1.483 |
| Period of revolution | from | 5.48 | to | 6.16 years. |

It may be seen that at present the perihelion distance has increased so much that the orbit has no longer an intersection point with the orbit of the Earth. These large and rather rapid changes of the comet's elements at any rate imply the possibility that the Corvid stream may be connected to this comet, the more as the Corvids are obviously undergoing strong additional perturbations by the Earth. Considering the facts that the Corvids are no doubt a cometary current of the Jupiter group, that besides Tempel 3-Swift no other fitting comet is known, that the meteors observed 1937 are moving in the plane of the comet's orbit and that their true anomaly approximately agrees with that of the comet, one can scarcely escape the conclusion that in June, 1937, the Earth might have met an isolated meteoric cloud which might have separated from the comet perhaps long ago.

[1] C. Hoffmeister, Meteorströme (Meteoric Currents). Weimar 1948. 286 pages, with extensive commentaries in English.
[2] Popular Astronomy, November, 1947.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa., 1949 August 17.

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## Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

**Edited by FREDERICK C. LEONARD**
**Department of Astronomy, University of California, Los Angeles 24**

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### A Preliminary Report on the Distribution of Gallium, Palladium, Gold, and Nickel in 45 Iron Meteorites*

Harrison Brown *and* Edward Goldberg

Institute for Nuclear Studies, University of Chicago, and Argonne National Laboratory, Chicago, Illinois

ABSTRACT AND INTRODUCTION

We have completed the analysis of 45 iron meteorites (siderites) for gallium, palladium, gold, and nickel, utilizing the neutron activation method of analysis for the first three elements named.[1,2] Nickel was determined by the method employed by Henderson,[3] and good checks were obtained with his analyses. The iron meteorites studied cover the complete range of classes, hexahedrites, octahedrites, and ataxites. Our results will be published in detail at a later date. In the meantime, certain features of the distributions are of sufficient interest to warrant a preliminary report.

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A coarse octahedrite, Linwood, Butler County, Nebraska, was found to possess the highest gallium content, 96.3 parts per million. Fish (or Great Fish)

*Read at the 12th Meeting of the Society, Los Angeles, California, 1949 September 6-8.

River (Bethany), Great Namaqualand, Southwest Africa, a nickel-rich ataxite, possessed the lowest gallium content, 0.43 part per million. Piñon, New Mexico, another nickel-rich ataxite, possessed the highest palladium content, 9.88 parts per million, and Coahuila, Mexico, a hexahedrite, possessed the lowest concentration of palladium, 1.44 parts per million. Bear Creek, Colorado, a finest octahedrite, was found to possess the highest gold content, 2.5 parts per million, and Fish River (*ante*), a nickel-rich ataxite, possessed the lowest concentration of gold, 0.094 part per million.

In general, iron meteorites appear to break down into 3 distinct classes with respect to their gallium contents. There is first a group of meteorites, mostly fine and finest octahedrites and nickel-rich ataxites, the members of which possess gallium contents of about 2 parts per million. The second group is composed largely of medium octahedrites. The gallium contents of this group run in the neighborhood of 20 parts per million. The third group, in which the gallium contents run from 45 to 100 parts per million, is composed largely of coarse and coarsest octahedrites and hexahedrites.

We find, in agreement with Henderson,[4] that nickel-poor ataxites appear to be identical, chemically, with hexahedrites; similarly, we find no significant chemical differences between finest octahedrites and nickel-rich ataxites.

Iron meteorites appear to form a continuum, with respect to their gold and palladium contents, rather than a series of classes, as in the case of gallium. In general, gold increases with increasing palladium, as one might expect, *a priori*; also, iron meteorites that possess the lowest concentrations of gallium possess the highest concentrations of nickel, palladium, and gold.

We believe that the observed distributions of elements are intimately related to the relative proportions of kamacite and taenite present in each meteorite. Further investigations will be necessary, however, before the relationships can be firmly established.

In the future, trace-element analysis may prove useful in identifying meteorites and in ascertaining whether or not two specimens are from really different falls. An example in this connection is provided by a comparison of the gallium, palladium, and gold contents of Canyon Diablo, Arizona, and Canyon Diablo No. 2. The latter meteorite is believed by Nininger[5] to be a meteorite distinct from the main Canyon Diablo fall. Our analyses are given below:

| | Ni (%) | Ga (p.p.m.) | Pd (p.p.m.) | Au (p.p.m.) |
|---|---|---|---|---|
| Canyon Diablo | 7.24 | 77.4 | 3.98 | 2.1 |
| Canyon Diablo No. 2 | 8.09 | 85.0 | 5.30 | 1.6 |

The concentrations of each element in the two meteorites are different in all cases, outside of experimental error. This result leads us to believe that Canyon Diablo No. 2 is a meteorite indeed distinct from Canyon Diablo.

REFERENCES

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[2] Edward Goldberg & Harrison Brown, *Analytical Chemistry* (in press).
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[4] E. P. Henderson, *Am. Min.*, **26**, 546, 1941.
[5] H. H. Nininger, *C.S.R.M.*, **2**, 193-7; *P. A.*, **48**, 328-32, 1940.

## Miscellaneous Notes on Meteorites from Holbrook, Richardton, Xiquipilco, and Mount Elden*

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ABSTRACT

From time to time, minor observations have been made on meteorites. These included the following: A Holbrook, Arizona, aerolite contained 0.23% of water-soluble salt, which included 0.02% of sulfate and a trace of calcium. The same stone had a variable moisture content, which depended upon the relative humidity of its surroundings. A Richardton, North Dakota, aerolite contained only 0.033% of moisture. A Xiquipilco, Mexico, siderite probably contained a trace of nitride. An analysis is given of the taenite in a Mount Elden, Arizona, siderite. Much of the graphite in this mass appeared to be cliftonite or otherwise crystalline.

1. *The Water-Soluble Salts of a Holbrook, Arizona, Aerolite.*—In a previous paper, I reported the presence of calcium, sulfate, and phosphate in a Holbrook, Arizona, aerolite (cl. = C,ck; C.N. = +1100,349), in the solution obtained by extracting the powdered aerolite with hot water.[1] Subsequently, ammonium compounds, to the extent of 0.0033% (as ammonia), were reported. Of these, 65% were removed by Soxhlet extraction with water.[2] Since that work was published, I have extracted a sample of pulverized Holbrook for 1 hour with boiling distilled water and weighed the soluble extract. The dissolved material had a slightly brownish color, due presumably to a doubtful trace of iron previously reported,[1] and its weight was equivalent to 0.23% of the oven-dried sample. Analysis of the salt for calcium yielded a figure of 0.0004%. Analysis for sulfate gave 0.020%. Both figures are based on the dry weight of the meteorite. Since the amount of soluble matter was very small, the accuracy of the analysis is probably less than is indicated by these figures.

2. *The Moisture Content of the Holbrook Aerolite.*—Before extraction, the pulverized sample was dried to constant weight in an oven at 120° C. The weight loss was equivalent to 1.02% of moisture. Another sample lost 0.31% when dried over sulfuric acid, and lost a total of 0.62% after drying in the oven. A third sample lost 0.16% when dried over calcium chloride. These determinations were made at different times, thus suggesting that the water content was dependent upon the prevailing relative humidity; consequently, the last sample was transferred to desiccators containing solutions that maintained a known relative humidity, and left in each until it attained a constant weight. The moisture contents measured by the gains in weight were as follows:

TABLE 1

| Relative Humidity | Moisture Content |
|---|---|
| 30% | 0.20% |
| 70% | 0.30% |
| 100% | 1.18% |

3. *The Moisture Content of a Richardton, North Dakota, Aerolite.*—A sample of the Richardton, North Dakota, aerolites (cl. = Cbr,cv; C.N. = +1023,466) lost only 0.033% of moisture at 110° C. In a container at relative humidity 100%, the moisture content rose to only 0.054%.

*Read at the 12th Meeting of the Society, Los Angeles, California, 1949 September 6-8.

4. *Nitride in a Xiquipilco, Mexico, Siderite.*—A sample of hack-saw dust from a Xiquipilco (= Toluca), Mexico, siderite (cl. = Om; C.N. = +0997,194) was first dissolved in dilute sulfuric acid and then made strongly alkaline with KOH. The vapors from the boiling solution were passed thru a capillary into Nessler's Solution by means of a slow current of nitrogen. An abundant grayish-green precipitate formed, but, after this had settled, small amounts of the characteristic orange precipitate produced by ammonia were found in the upper part of the solution and in the tip of the capillary. It appears therefore that this meteorite contained either free ammonia or, more likely, an iron nitride such as silvestrite (siderazote), $Fe_8N_2$.[3] The greenish precipitate may have been caused by phosphine.

5. *Taenite and Cliftonite in a Mount Elden, Arizona, Siderite.*—Fragments resulting from the excessive rusting of a Mount Elden (= Canyon Diablo?), Arizona, siderite (C.N. = +1116,353) were treated with dilute sulfuric acid. The graphitic residue contained bright spangles of magnetic metal soluble in *aqua regia*. Analysis of the solution gave:

| Fe | Ni | Co | P | Total |
|---|---|---|---|---|
| 81.60% | 18.45% | Nil | Nil | 100.05% |

FIG. 1

A PHOTOMICROGRAPH (×75) OF A MOUNT ELDEN, ARIZONA, SIDERITE SHOWING THE POLYGONAL STRUCTURE OF THE METAL AND THE HEXAGONAL CROSS-SECTIONS OF THE GRAPHITE CRYSTALS. PHOTOGRAPH BY COURTESY OF L. F. BRADY.

Taenite contains usually more nickel than this, but analyses with less have been reported. Examination of the residue of graphite revealed that many of the interfaces between it and the original metal were crystal faces. Cubes, dodecahedrons, and octahedrons were identified. Since these are isometric forms, whereas graphite is normally rhombohedral, it is probable that these crystal faces were cliftonite. Much more abundant were needle-shaped crystals with indistinct ends. In one case a fascicle of them was curved, as tho they had been subjected to a shearing force. When distinct, the cross-section was hexagonal, but most of them showed more or less pronounced longitudinal striations somewhat reminiscent of tourmaline prisms. A photomicrograph by Mr. L. F. Brady of a Mount Elden siderite (Fig. 1) shows some of them in cross-section. There is a tendency for the hexagons to be divided into 3 diamond-shaped areas differing slightly in color. The larger graphitic masses are sometimes foliated, as tho composed of a great number of such prisms, but more often the material is finely granular and apparently structureless. The Mount Elden graphite contained 11.10% of ash.

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[1] J. D. Buddhue, *Am. Min.*, **26**, 677-80, 1941.
[2] J. D. Buddhue, *C.S.R.M.*, **3**, 59-61; *P. A.*, **50**, 560-3, 1942.
[3] O. Silvestri, *Gazz. chem. ital.*, **5**, 301, 1875; *Pogg. Ann.*, **157**, 165, 1876; reviewed by F. W. Clarke, *U.S.G.S. Bull. 770*, p. 274, 1924.

## The Polar Coördinate Number of a Meteoritic Fall*

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ABSTRACT

The polar coördinate number (PCN) of a meteoritic fall is defined and compared with the previously introduced coördinate number, now called, for distinction, the equatorial coördinate number (ECN). Each variety of number has its own peculiar advantages, which are briefly discussed.

What will henceforth be termed the equatorial coördinate number (ECN) of a meteoritic fall has already been generally defined in a previous paper.[1] What will now, for distinction, be called the polar coördinate number (PCN) of such a fall shall be defined as a $2n$-digit[2] number, of which the first $n$ digits shall equal the longitude of the actual place of fall plus 180°, this coördinate being measured *westward*[3] from the 180° meridian and having a value $<360°$, and the last $n$ digits shall equal the south polar distance,[4] which is $\leqslant 180°$, each coördinate being expressed in units of $10^{3-n}$ degree.

Even tho the PCN contains one more digit than the analogous ECN, the PCN has the following advantages: (1) the sequence of digits in the PCN of every *coördinate mesh*[5] on the surface of the globe is unique, whereas the sequence of digits in every ECN corresponds to 4 coördinate meshes; and (2) the PCN is always positive—therefore no algebraic sign need be employed in connection with it.

If the geographical coördinates of a place, longitude and latitude, be denoted by $\lambda$ and $\phi$, the first $n$ digits of its PCN by $d\lambda$,† and the last $n$ digits by $d\phi$, then, in the case, *e.g.*, of its 8-digit PCN,

*Read at the 12th Meeting of the Society, Los Angeles, California, 1949 September 6-8.

†Here and elsewhere in this paper, in $d\lambda$ and $d\phi$ $\lambda$ and $\phi$ are to be understood as subscripts.

$$d\lambda = \lambda + 1800,\ d\phi = \phi + 0900;\ \text{whence, obviously,}$$
$$\lambda = d\lambda - 1800,\ \phi = d\phi - 0900,$$

$\lambda$ and $\phi$ being here expressed in units of 0°.1.

Such formulae readily enable the PCN to be computed if the geographical coördinates are known, and *vice versa*. In using formulae of this sort it must be remembered, of course, that geographical longitude ($\lambda$) is, by convention, measured from the prime meridian of Greenwich positively westward, from 0° to +180°, and negatively eastward, from 0° to —180°, whereas latitude ($\phi$) is measured from the equator positively northward from 0° to +90° and negatively southward from 0° to —90°, and that both $\lambda$ and $\phi$, like the equation of time ($E$), implicitly carry their own signs.

The following table gives, for comparison, the 7-digit ECN and the corresponding 8-digit PCN of the 4 representative falls used as illustrations in my earlier paper.[1]

TABLE 1

THE ECN's AND THE PCN's OF 4 REPRESENTATIVE FALLS

| Name of Fall | ECN | PCN |
|---|---|---|
| Canyon Diablo, Coconino County, Arizona, U.S.A. | +1110,350 | 2910,1250 |
| Otumpa, Tucuman, Gran Chaco Gualamba, Argentina | ±0615,275 | 2415,0625 |
| Ensisheim, Alsace, France | ∓0074,479 | 1726,1379 |
| Hoba, near Grootfontein, Southwest Africa | —0179,196 | 1621,0704 |

It is not intended that the PCN shall replace the ECN. Each kind of number has its own peculiar advantages, just as has each of the several coördinate systems current in astronomy. The ECN, being made up explicitly of the geographical coördinates of the place of fall, gives these coördinates directly; moreover, as has already been remarked, this number contains one less digit than does the corresponding PCN. On the other hand, the sequence of digits in the PCN of every coördinate mesh is unique, and the number itself, being always entirely positive, does not require the use of any algebraic sign; consequently the PCN may possess certain advantages over the ECN for cataloging and computational purposes and for numbering specimens in collections—*i.e.*, in serving, in the systematic enumeration of meteoritic falls, as a serial or reference number, from which, however, the geographical coördinates of the place of fall are easily calculable.[6]

References and Notes

[1] *C.M.S.*, **4**, 82-4; *P. A.*, **55**, 553-5, 1947.

[2] Where $n$ is a positive integer $\geqslant 3$.

[3] *I.c.*, in a counterclockwise direction, as viewed from the south pole, or in the direction opposite to that in which the Earth rotates.

[4] This may be defined as the angular great-circle distance measured from the south pole to the place in question; it is comparable to the celestial coördinate known as north polar distance ($P$), which is the complement of the declination ($\delta$). On the surface of the Earth, north polar distance would be the complement of the latitude ($\phi$), whereas south polar distance (for which the symbol $\sigma$ may be used) is evidently $90° + \phi$. Since, in accordance with the prevailing conventions, longitude increases *algebraically* westward from the 180° meridian, and latitude northward from the south pole, PCN's are so defined as to increase conformably; hence the choice of the 180°, instead of the 0° (Greenwich), meridian, and of south, rather than north, polar distance, in their definition.

[5] This term is defined in the first paragraph of the paper cited in ref. (1), *ante, q. v.*

[6] There is no possibility of confusing the PCN with the correspondent ECN, inasmuch as the former has one more digit than the latter and is signless.
1949 June 16

## Some Remarks on the Origin of Earthly Meteorites*

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ABSTRACT

In general, *fallen* meteorites are probably of planetary origin, whereas *consumed* meteorites, perhaps in most cases, if not in all, are of cometary origin. The latter variety of bodies are evidently of insufficient mass to escape total vaporization within the Earth's atmosphere. Since no comet—and probably no meteorite, either—has ever been showed to have been traveling on an unmistakably hyperbolic heliocentric orbit, if Earthly meteorites are of planetary and cometary origin, their elliptic heliocentric orbits and their origin within the Solar System are readily explained.

The problem of the origin of astronomical bodies is always difficult and frequently insoluble. Fortunately for the meteoriticist, the problem of the origin of fallen meteorites here on the Earth and of those meteorites that are entirely consumed in flight in the Earth's atmosphere has turned out to be the least difficult of all such problems: doubtless more is now known about the origin of fallen and consumed meteorites than about that of any other kinds of bodies in the Universe.

Thanks largely to the recent experimental work of Dr. Harrison Brown and his collaborators, the old hypothesis—independently advanced by several authors[1]—that *fallen* meteorites are the debris of a disrupted planet or planets, essentially similar in physical constitution and mineral composition to the Earth, has been strikingly confirmed. On the other hand, those meteorites that are completely volatilized in flight and make themselves known only by the luminous phenomena or so-called *meteors* that they produce in rushing thru the Earth's atmosphere have in many cases been conclusively demonstrated to be particles of cometary origin.[2]

A comet has been defined as "a swarm of meteorites [the nucleus] and their concomitant exhalations [the coma and the tail] in motion thru space."[3] Apparently the small solid particles that become detached from the head of a comet and are strewn along its path and that come close enough to the Earth to be drawn into its atmosphere are, in most cases, if not in all, those tiny celestial masses that are entirely vaporized in flight and are known only by the meteors they generate.

Altho several meteorites are on record as having fallen, quite fortuitously to be sure, in the course of meteoric showers, no fallen meteorite has ever been proved to have been a member of such a shower. Evidently the bodies that give rise to meteoric showers, and also those that are the cause of ordinary sporadic meteors—of which both categories are presumably of cometary origin—are simply of insufficient mass to penetrate the Earth's atmosphere unconsumed, whereas the more sizable masses, which may be the disintegrational products of a defunct planet or planets—or themselves miniature planets—are often massive enough to

*Read at the 12th Meeting of the Society, Los Angeles, California, 1949 September 6-8.

pass entirely thru the atmosphere and to land upon the Earth's surface as fallen meteorites.

This, then, may be the explanation of the difference between fallen meteorites and consumed meteorites—the former are probably, in general, of planetary origin, having been obviously of sufficient initial mass completely to penetrate the Earth's atmosphere as solid bodies, whereas the latter are, in all likelihood, usually of cometary origin, having been evidently of too exiguous mass to pass entirely thru unvaporized.

Furthermore, since no comet—and probably no meteorite, either—has ever been showed to have been revolving around the Sun on an unquestionably hyperbolic orbit, if Earthly meteorites are of planetary and cometary origin, their elliptic heliocentric orbits and their origin within the Solar System are readily explained.

REFERENCES AND NOTE

[1] *V., e.g.*, a note on the subject by the present writer, published as long ago as 1934, in *N.S.R.M., P. A.*, **42**, 158-9.

[2] That some consumed meteorites, as well as all fallen meteorites, are of planetary origin is, of course, a possibility that should not be overlooked, even tho little if any *observational* evidence can be adduced to support it.

[3] *C.S.R.M.*, **3**, 250; *P. A.*, **54**, 153, 1946.

## Further Evidence concerning the Wolf Creek, Western Australia, Crater (—1278,192)*

Under date of 1949 May 10, Mr. J. Fraser Paterson of Broken Hill, New South Wales, Australia, has kindly forwarded us a copy of *The Australian Journal of Science*, **11**, No. 5, April, 1949, which, on pp. 154-6, contains an article by Frank Reeves and R. O. Chalmers on "The Wolf Creek Crater." The geographical coördinates of the Crater, as reported in that paper, are long. E. 127° 46′, lat. S. 19° 10′; so its 7-digit equatorial coördinate number (ECN) is —1278,192. The following excerpts from the article give additional information about the Crater to that conveyed in the notes published in the current March and August issues of *C.M.S.*

"A party sent out by the Australian Geographical Society examined [the Crater] in August, [1948,] and an article describing the Crater was published in the Society's magazine, *Walkabout*, for November, 1948 ('The Hidden Crater of Wolf Creek,' by Charles H. Holmes). During the same month a geological party from the Commonwealth Bureau of Mineral Resources, headed by R. S. Matheson and D. J. Guppy, spent two days at the Crater and discovered evidence of its meteoritic origin. The following is part of Matheson's report on the Crater:

" 'During the course of the investigations, ironstone fragments, which are probably of meteoritic origin, were discovered for the first time. These are abundant on the rim of the southwest sector, and elsewhere occur only as scattered fragments. These ironstone fragments are decomposed, rounded, and exhibit a "breadcrust" structure, and their physical character appears to be similar to fragments of decomposed meteoritic iron obtained around the large Meteorite Crater in Arizona, U.S.A. The ironstone fragments are up to about 6 inches in diameter. Specimens of the ironstone fragments have been submitted to the West Australian Chemical Laboratories for analysis and confirmation of their meteoritic origin.

" 'The abundance of meteoritic ironstone around the rim in the southwest

*Read at the 12th Meeting of the Society.

sector suggests that this is the out-throw side after explosion, and that the meteorite, prior to impact, was traveling from north-northeast to south-southwest. Scattered quartzite boulders outside the rim rock on the southwest side also suggest that this is the out-throw side of the Crater.'

"A specimen of the ironstone given to Reeves by D. J. Guppy was sent to R. O. Chalmers at the Australian Museum, [Sydney,] who concludes that it is the weathered product of an iron meteorite. Chalmers' report on the specimen follows:

"'A specimen of this material sent by Dr. Frank Reeves was examined. Superficially it appears to be what is commonly called "ironstone." It is dark reddish-brown, and a good deal of the specimen has a varnish-like luster. [A] portion of the specimen is covered with a light reddish-brown earthy coating. In places thin veins of reddish hematite can be seen. The specimen is not homogeneous, because some portions show a typical red hematite streak and other portions show the yellowish-brown streak of limonite. An incrustation of unidentified, pale yellowish-green mineral, no doubt containing nickel, was noted in two places. The specimen contains 1.9% of NiO. It is therefore an oxidation product of an iron meteorite. It is practically identical in appearance with the "iron-shale" described from the Henbury Meteorite Craters in Central Australia. . . . Such oxidation products of iron meteorites are described also from other localities, including the famous Meteorite Crater of Canyon Diablo in Arizona, U.S.A.

"'Such material is usually referred to in the literature as "iron-shale," and is usually said to consist of limonite. The specific gravity of this specimen as a whole is 4.05, which indicates that it consists largely of limonite. The nickel content indicates that something else is present, and this is no doubt trevorite ($NiO \cdot Fe_2O_3$), which is magnetic and would account for the fact that small fragments of the specimen are magnetic. . . .

"'It would be interesting if unoxidized specimens of the meteorite were discovered, because a comparison between the original nickel content and that of the "iron-shale" would indicate what leaching of nickel has taken place, and thus might throw some light on the age of the fall. Nininger (1938) showed that nickel is lost from meteorites in the course of weathering. This is indicated also by the fact that a trace of nickel appeared in the water in which the Wolf Creek specimen was boiled for determination of specific gravity.'"

There seems to be little question, then, in view of the foregoing evidence, that the Wolf Creek Crater is the second largest known meteoritic crater of the world.—F.C.L.

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### Dr. John A. Russell Appointed Secretary of the Society

As of date 1949 September 8, that of the adjournment of the 12th Meeting of the Society, Mr. Oscar E. Monnig, of 1010 Morningside Drive, Fort Worth 3, Texas, because of the pressure of his personal business, resigned from the secretaryship of the Society. Dr. John A. Russell, Associate Professor and Head of the Department of Astronomy of the University of Southern California, Los Angeles 7, California, a charter member of the Society and for many years active in its affairs, was, in accordance with Art. 3, Sect. 8, of the Constitution of the Society (*v. C.S.R.M.*, **2**, 324, 1941), appointed by the Council, at the 12th Meeting, to succeed Mr. Monnig as Secretary and to serve during the remainder

of the 1946-50 term. Any communications intended for the Secretary's office should, then, be henceforth directed to Dr. Russell, at the forenamed address.

*President of the Society:* ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

*Secretary of the Society:* JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

# VARIABLE STARS

## Variable Star Notes from the American Association of Variable Star Observers

**By LEON CAMPBELL, Recorder**

*Nova Scuti, 1850o4:* Another nova made its appearance late in July in the constellation of Scutum. It was found on a Meudon photograph taken by M. Charles Bertaud of that Observatory, and was of photographic magnitude 9.6 on July 31. Its position for 1900 is R.A. $18^h\ 50^m9$, Dec. $-4°\ 20'$. Proof that it was a nova was obtained at the McDonald Observatory early in August when it had a photographic magnitude of 8.5. A plate taken there showed the spectrum to be that of a nova with an F5 classification, without emission in the photographic region. A spectrum plate secured at Ann Arbor by McLaughlin and Weston revealed bright hydrogen and weak enhanced iron lines, and the absorption spectrum resembled that of an extreme supergiant type such as is found in the eclipsing variable Epsilon Aurigae.

With the aid of copies of the BD chart of the region issued to AAVSO observers, the light changes have been noted since early in August, and the brightness had steadily decreased to visual magnitude 10.0 on September 1.

*Current Notes on AAVSO Variables:* An examination of the current plots reveals the following facts concerning the variables on the AAVSO observing program.

T Cas, 001755. Well down to minimum.

R And, 001838. Faint and near minimum.

o Cet, 0214*03*. At maximum, brighter than 3rd magnitude; a very rapid rise.

R Ret, 043*263*. Well observed maximum, magnitude 7.9, at JD 2433070.

R Aur, 050953. At maximum with a well-defined still-stand at magnitude 10.7 on the way to maximum.

T Pic, 051247. Well observed maximum, magnitude 8.3 at JD 2433062.

SU Tau, 054319. An R CrB-type variable, still at normal maximum brightness, but which should be closely watched for its next drop to minimum.

R Oct, 055*686*. Maximum observed, magnitude 8.6, at JD 2433048.

SS Aur, 060547. SS Cygni-type variable, broad maximum, magnitude 10.8, observed at JD 2433009.

RR Pic, 0634*62*. Nova of 1924, practically constant at magnitude 10.9.

U Gem, 074922. SS Cygni-type variable. A wide maximum, magnitude 9.2, was observed at JD 2433050.

Nova Pup, 0808*35*. Practically constant at magnitude 10.8.

Z Cam, 081473. Still shows no evidence of the usual short, periodic fluctuations in light; nearly constant at magnitude 11.8.

S Pyx, 0900*24*. Well observed maximum, magnitude 9.7, at JD 2433050.

R Car, 092962. Well observed maximum, magnitude 4.6, at JD 2433050.

T UMa, 123160. Well observed maximum, magnitude 7.9, at JD 2433098.

R Vir, 123307. Observed minimum, magnitude 11.2, JD 2433088.

RS UMa, 123459. Observed maximum, magnitude 9.3, JD 2433078.

R Hya, 132422. At maximum, magnitude 5.6, JD 2433066, not as bright as usual.

S Vir, 132706. At maximum, magnitude 7.1, JD 2433048.

T Cen, 133633. At maximum, magnitude 5.5, JD 2433029; at minimum, magnitude 8.2, JD 2433069.

R Boo, 143227. At minimum, magnitude 12.1, JD 2433027; at maximum, magnitude 7.1, JD 2433119.

S Aps, 145971. R CrB-type variable. Still near minimum. An increase in brightness from magnitude 14.0 to 12.8 occurred in May of this year.

RS Lib, 151822. Minimum, magnitude 12.7, JD 2433074.

R CrB, 154428. Well on its way to maximum, magnitude 9.0 on JD 2433162 (September 2). Because of possible irregularities on the rise, the star should be closely observed.

X CrB, 154536. Observed maximum, magnitude 9.3, JD 2433078.

S Ser, 154715. Observed maximum, magnitude 5.7, JD 2433097.

U Ser, 160210. Observed maximum, magnitude 8.4, JD 2433059.

W Oph, 161607. Observed maximum, magnitude 9.5, JD 2433073.

SS Her, 162807. Observed maximum, magnitude 9.3, JD 2433087.

S Her, 164715. Observed maximum, magnitude 7.1, JD 2433075.

RV Her, 165631. Observed maximum, magnitude 9.7, JD 2433027.

R Oph, 170215. Observed maximum, magnitude 7.6, JD 2433087.

RU Oph, 172809. Observed minimum, magnitude 13.5, JD 2433075.

U Ara, 174551. Observed maximum, magnitude 9.0, JD 2433067.

R Pav, 180363. Observed maximum, magnitude 8.2, JD 2433068.

Nova (DQ) Her, 180445. Faint, magnitude 13.6.

T Her, 180531. Observed minimum, magnitude 12.9, JD 2433030; observed maximum, magnitude 7.3, JD 2433114.

W Lyr, 181136. Observed maximum, magnitude 8.0, JD 2433082.

R Sct, 184205. No deep minima. Observed maximum, magnitude 5.2, JD 2433024; observed minimum, magnitude 5.9, JD 2433057; observed maximum, magnitude 5.3, JD 2433080; observed minimum, magnitude 5.9, JD 2433116.

T Sgr, 191017. Observed maximum, magnitude 7.6, JD 2433050.

RY Sgr, 191033. R CrB-type variable at maximum, magnitude 6.5.

R Cyg, 193449. Observed maximum, magnitude 8.2, JD 2433072.

RT Cyg, 194048. Observed minimum, magnitude 12.2, JD 2433100.

Chi Cyg, 194632. Slight still-stand at magnitude 10.7 on increase to maximum, magnitude 5.5, JD 2433158 (August 29).

UU Aql, 195109. SS Cygni-type variable, observed narrow maximum, magnitude 11.8, JD 2433123.

RR Tel, 195656. Peculiar variable. Still bright, magnitude 6.8. (Could this star be a recurring nova?)

V Sge, 201520. Irregular variable, fluctuating between magnitude 10.6 and 12.7.

T Aqr, 204405. Observed maximum, magnitude 7.8, JD 2433060.

R Vul, 205923a. Observed minimum, magnitude 12.9, JD 2433085.

T Cep, 210868. Observed maximum, magnitude 5.8, JD 2433055.

SS Cyg, 213843. Narrow maximum, magnitude 9.0, JD 2433053, and wide maximum, magnitude 8.3, JD 2433120.

RU Peg, 220912. SS Cygni-type variable, narrow maximum, magnitude 10.6, JD 2433119.

V Cas, 230759. Observed maximum, magnitude 8.3, JD 2433077.

*Observations received during July and August, 1949:* A total of 8,456 observations was received—4,177 in July and 4,279 in August—from the following 82 observers.

| | July—1949—August | | | | | July—1949—August | | | |
|---|---|---|---|---|---|---|---|---|---|
| Observer | No. Obs. | No. Ests. | No. Obs. | No. Ests. | Observer | No. Obs. | No. Ests. | No. Obs. | No. Ests. |
| Adamopoulos | 4 | 4 | ... | ... | Kirchhoff | 40 | 120 | ... | ... |
| Adams | 20 | 56 | 16 | 52 | Knowles | 3 | 13 | 3 | 12 |
| Ahnert | 39 | 154 | 35 | 266 | de Kock | 126 | 572 | 114 | 500 |
| Bajocchi | 10 | 15 | 19 | 39 | Kratz | 3 | 6 | 2 | 2 |
| Bartha | 5 | 7 | ... | ... | Lacchini | 58 | 90 | 53 | 70 |
| Bicknell | 16 | 139 | ... | ... | Lankford | 12 | 14 | 28 | 85 |
| Blunck | 13 | 14 | 14 | 14 | Ledbetter | 17 | 19 | ... | ... |
| Bogard | 57 | 136 | 35 | 63 | Lee | ... | ... | 14 | 29 |
| Buckstaff | 20 | 30 | 18 | 42 | Lovas | 3 | 3 | ... | ... |
| Bufkin | 3 | 3 | 3 | 3 | Lowder | 24 | 40 | 9 | 10 |
| Burkhead | 1 | 4 | ... | ... | LeVaux | 20 | 21 | 44 | 51 |
| Cain | 4 | 6 | 11 | 13 | Luft | 5 | 13 | 5 | 15 |
| Charles | 23 | 29 | 20 | 42 | Miller | 28 | 37 | 8 | 8 |
| Chassapis | 94 | 191 | ... | ... | Oravec | 51 | 170 | 34 | 90 |
| Cragg | 89 | 91 | 113 | 119 | Parker | 11 | 11 | 38 | 38 |
| Carroll | ... | ... | 14 | 21 | Parks | 25 | 36 | 26 | 36 |
| Dafter | 7 | 24 | ... | ... | Pearcy | 43 | 43 | 29 | 34 |
| Daley | 6 | 12 | 9 | 24 | Peltier | 155 | 228 | 182 | 256 |
| Darling | 11 | 18 | ... | ... | Penhallow | 23 | 37 | 48 | 93 |
| Darnell | 1 | 4 | 1 | 5 | Pierson | 80 | 106 | 28 | 28 |
| Davis | 13 | 18 | 18 | 68 | Plakidis | 12 | 32 | ... | ... |
| Dillon | 6 | 11 | 5 | 9 | Reeves | ... | ... | 1 | 2 |
| Drakakis | ... | ... | 16 | 237 | Renner | 102 | 102 | 138 | 140 |
| Edelenyi | 4 | 4 | ... | ... | Rich | ... | ... | 4 | 9 |
| Erickson | 23 | 54 | ... | ... | Rosebrugh | 16 | 73 | 12 | 86 |
| Escalante | 14 | 19 | ... | ... | Schoenke | ... | ... | 2 | 2 |
| Estremadoyro, G. A. | ... | ... | 4 | 5 | Snow | ... | ... | 3 | 3 |
| Estremadoyro, V. A. | ... | ... | 1 | 1 | Stevens | ... | ... | 9 | 17 |
| Fernald | 226 | 646 | 259 | 823 | Svolopoulos | 4 | 4 | 6 | 6 |
| Focas | 5 | 6 | ... | ... | Taboada | 33 | 35 | ... | ... |
| Ford | 5 | 5 | 14 | 14 | Tarbell | 10 | 27 | 10 | 31 |
| Gingerich | 8 | 11 | 4 | 7 | Tifft | 22 | 22 | 95 | 201 |
| Greenley | 50 | 125 | 58 | 105 | Toth | 15 | 38 | ... | ... |
| Halbach | ... | ... | 15 | 16 | Upjohn | 48 | 50 | 55 | 59 |
| Hamilton | 3 | 6 | 2 | 2 | Venter | 15 | 37 | 10 | 17 |
| Hartmann | 120 | 131 | 133 | 139 | Water | 2 | 2 | 9 | 9 |
| Herring | 29 | 51 | 29 | 79 | Webb | 18 | 19 | 15 | 17 |
| Holloway | ... | ... | 12 | 20 | Weber | 50 | 50 | 50 | 50 |
| Kantor | 12 | 49 | ... | ... | Welch | ... | ... | 5 | 5 |
| Kelly | 11 | 11 | 10 | 10 | Wells | ... | ... | 8 | 8 |
| | | | | | Werntz | 9 | 23 | 15 | 31 |
| | | | | | Zadunaisky | 1 | 30 | ... | ... |

September 15, 1949.

## Comet Notes

By DANIEL L. HARRIS III

Comet activity continues to be slow, only three new comets having been found this year. COMET 1949 *a* (JOHNSON) is too near the sun to be observed at the present time, but as it does not pass perihelion until January, 1950, it will be observed as a morning object later this year. The second comet discovered this year (COMET 1949 c (BAPPU-BOK-NEWKIRK) comes to perihelion October 26. The positions for the beginning of October are

| | α<br>h m | δ<br>° ′ |
|---|---|---|
| Oct. 3.0 | 15 32.9 | +37 13 |
| Oct. 11.0 | 15 30.2 | +36 22 |

and the predicted magnitude is about 13.

In order to avoid complications that might arise, the designation 1949 *b*, which was given to Bester's observations of COMET 1948 *h* (WIRTANEN), will not be used.

On August 24 Johnson discovered his second comet of the year 1949 *d*. This has not been observed by northern observers to my knowledge, but elliptical elements have been determined at Cape Town. The period is about 7 years, the eccentricity about 0.4, and the inclination about 13½°, all of which characterizes this as a typical short-period comet.

"The Handbook of the British Astronomical Association" lists eleven periodic comets expected to be visible in 1949. Four of these were recovered in 1948 and two others, COMET 1925 II (SCHWASSMANN-WACHMANN 1) and COMET 1942 VII (OTERMA) are visible every year. COMET 1916 II (NEUJMIN 2) and COMET 1927 VI (GALE) have been recovered at only one return and neither was found this year. It appears that these two comets are lost and will have to be rediscovered.

Of the three comets expected later this year, COMET 1939 IV (VÄISÄLÄ 1) and COMET 1928 I (REINMUTH 1) will be faint objects of about the 16-17th magnitude. The third comet, COMET 1945 *c* (DU TOIT) which is expected to return to perihelion in November is of special interest because of its short period of 4½ years. Only Encke's comet has a shorter period than this.

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## Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

### New Aspects of Meteoritical Study Suggested

Speculations to be of scientific interest, even though of no immediate value, must be based on reasonable assumptions. It is hoped that the suggestions to be made are not so far from reasonableness as to be boring. Meteoritics, in the belief of the writer, will soon be in an experimental stage. We can find evidence of steps in this direction in the recent laboratory attempts to produce synthetic

meteorites, in the construction of a supersonic wind tunnel to duplicate the conditions of flight in the high rarefied atmosphere, a hint in the heating to almost redness of V2 rockets in their plunge to earth, and especially in the recent attempt to produce artificial meteors by firing charges from V2 rockets in flight.

To date no one has suggested, at least publically, an experiment in which a small rocket would be fired downward to the earth after being carried to a great height by a large rocket. Meteoric velocities would be readily attained by the small rocket causing it to become an artificial fireball of considerable size and brilliance. The head of such a rocket would be a mass of known weight and shape, which would be checked against the head when recovered as an artificial meteorite. Telemetering from the rocket in its downward flight and planned observations by various means from the ground would furnish a host of new data and shed light on many lines of research. Perhaps an immediate practical value would result for we would not want our long-range rockets to become fireballs when they reach their targets in the event of war. Fireball observations are often at variance with each other and insufficient, and such a controlled experiment would indicate proper directions of study. It may even solve the question of ethaerial sound.[1]

Speculating on the various aspects of such an "Operation Fireball" has led the writer into many meteoritic byways. One could, for instance, form an opinion that the peculiar pittings and "thumb marks" on meteorites are due primarily to cavitation[2] and sonic phenomena. The highly turbulent, heated, and compressed atmosphere before a meteorite would be excellent medium for cavitation and sonic oscillations of tremendous amplitudes. Such effects are a factor in many engineering problems as in the wear of ship propellers. Cavitation phenomena and resonance of the meteorite to powerful sound vibrations may be a prime cause of explosive shattering of some meteorites. The Boogaldi meteorite as shown in a plate on page 72 in Farrington's "Meteorites" shows what may be evidence of powerful sound vibrations that determined the configurations of waves and ridges seen on it.

Meteors are the only means at present of studying hypersonic velocities but we cannot learn as much from them as we could from an artificial fireball. Of the many ideas arising from consideration of such velocities, one strikes the writer's fancy. The shock wave would be so powerful that it could well explain much of the luminosity of a meteor which is still largely a problem. The shock wave would be incandescent itself and, extending for large distances from the meteor, would account for the great size of the cylinder of luminosity. If this be true, a neat explanation of flickering meteors comes to mind. Only a person who has seen a few in the course of observing one or two thousand meteors can appreciate the remarkableness of flickering meteors. A meteor with an indentation or hollow in its forward end would act as a Hartmann air jet oscillator[3] and produce an oscillatory shock wave with regular variations in luminosity. A further source of a meteor's light might be fluorescence and ionization induced by the shock wave. Such effects are recognized phenomena in ultrasonics. Luminous shock waves may also act as antennae in radiating the electrical energy of the meteor.

Somewhat timidly, the writer would suggest that meteors are an important factor in the existence of the radio reflecting layers. When a steel ball is dropped from a height into water it carries with it twenty times its volume of air into the water and does not release it until its motion stops. A bullet fired into water carries a hundred times its volume of air into the water. At hypersonic speeds a

meteor may be of vastly greater effectiveness in dragging air. The meteor would act as a sort of molecular pump beginning at a height of 125 or 150 miles, the height of the F layer, and carrying air to the 50 or 70 mile high E layer. When it is considered that meteors are an effective factor in the ionization of the upper atmosphere, placing an equal significance on such a pump action by meteors, which in turn would affect the degree of ionization due to the increased density of the atmosphere at the E layer level caused by the meteors, then the idea does not seem too wild. The results of the pump action may have been cumulative at first up to a certain point after which the yearly infall of billions of meteors holds the density of the E layer at a high critical level. Although only briefly mentioned here the idea can be shown to agree on other points with facts and accepted theory.

We have much to learn from meteors, so much that the writer believes that meteoritics will become a truly practical astronomy.

REFERENCES

[1] See *C.S.R.M.*, **2**, 79-81; *P. A.*, **47**, 97-9, 1939, Nininger; also *P. A.*, **54**, 433-435, Anyzeski.

[2] See "Supersonics," Brown University, 1939. R. W. Wood. Pages 111-115.

[3] See "Supersonics" above. Pages 14-28.

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## General Notes

**Dr. Daniel M. Popper** was, on 1949 July 1, promoted from Assistant to Associate Professor of Astronomy in the University of California, Los Angeles.

**Dr. Miriam W. Jaffe,** formerly on the faculty of Wellesley College, was, on 1949 September 1, appointed Instructor in Astronomy in the University of Southern California.

**Dr. W. F. Prouty,** Professor of Economic and Structural Geology at the University of North Carolina since 1919 and head of the Geology Department since 1933, well known for his research on the so-called "Carolina Bays," died in Chapel Hill on June 27, 1949.

**Dr. John A. Russell,** Head of the Department of Astronomy of the University of Southern California, was, on 1949 September 1, promoted from Assistant to Associate Professor of Astronomy. On 1949 September 8, Dr. Russell was appointed Secretary of The Meteoritical Society, in succession to Oscar E. Monnig, of Fort Worth, Texas, who resigned.

**Wanted:** Some one who can tell the approximate age of a 4-inch refracting telescope made by H. Fritz, New York. This telescope has been in the possession of Washington and Jefferson College for the past sixty years. Anyone interested should communicate with Raymond M. Bell, Professor of Physics, Washington and Jefferson College, Washington, Pennsylvania.

**Provisional Relative Sunspot Numbers for August, 1949***

| | | | | | |
|---|---|---|---|---|---|
| 1 | 161 | 11 | 17 | 21 | 151 |
| 2 | 171 | 12 | 56 | 22 | 198 |
| 3 | 127 | 13 | 82 | 23 | 189 |
| 4 | 114 | 14 | 108 | 24 | 169 |
| 5 | 109 | 15 | 155 | 25 | 158 |
| 6 | 88 | 16 | 174 | 26 | 163 |
| 7 | 59 | 17 | 175 | 27 | 165 |
| 8 | 50 | 18 | 168 | 28 | 163 |
| 9 | 45 | 19 | 162 | 29 | 155 |
| 10 | 34 | 20 | 192 | 30 | 133 |
| | | | | 31 | 168 |

August Mean R = 130.9

Predictions of the smoothed monthly sunspot numbers for the coming 6 months:

| | | | |
|---|---|---|---|
| September | 118 | December | 107 |
| October | 115 | January | 102 |
| November | 111 | February | 98 |

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

### Dr. Van Biesbroeck as Consultant

Dr. G. Van Biesbroeck of the Yerkes Observatory of the University of Chicago, Williams Bay, Wisconsin, left on September 3 for Brussels (Belgium) to confer with the Institute of Scientific Research in Central Africa. The purpose of this organization is to establish in the Congo a Research Institute covering different aspects of science, one of which requires an astronomical observatory. Professor Van Biesbroeck goes as consultant to work out the details of this project and to lead an expedition through the Belgian Congo to locate the most suitable site. Climatic conditions are the determining factor but facilities of access, available sources of power and supplies have to be considered. The possibilities of the high plateau of the Katanga in the interior and the mountainous region along Lake Tanganyika will be especially studied during a five-month exploration. The return trip will be by way of the Egyptian Sudan, a region that is on the central line of a total eclipse of the sun which takes place in February, 1952. The National Geographic Society of Washington has asked Dr. Van Biesbroeck to go over this territory in order to find an appropriate location for the American party that will be sent over there to observe the eclipse. Dr. Van Biesbroeck expects to be back by March 1.

### University of California Acquires Mirror For Big Telescope*

The mirror for the world's second largest telescope, the projected 120-inch sky searcher at the University of California's Lick Observatory, has been acquired by the University, President Robert G. Sproul has announced.

The mirror, acquired from the California Institute of Technology for $50,000, is being stored in a San Jose warehouse until a dome on this mountain observatory is completed to house it.

The 120-inch disk was cast in 1933, for the purpose of testing the principles later incorporated in the 200-inch mirror of the Mount Palomar telescope. Because of a change in testing procedure, the mirror was never used.

Dr. C. D. Shane, director of the Lick Observatory, said that original plans

*University of California Clip Sheet, September 6, 1949.

for the University's 120-inch instrument called for a conventional solid disk mirror. When recent tests proved beyond any doubt that the experimental, ribbed design of the 200-inch telescope was practicable, Lick astronomers decided that the test mirror could be used in their own instrument. The mirror is of the same design as that of the 200-inch.

Purchase of the mirror has advanced the 120-inch telescope project by two years, Dr. Shane said. Plans for the project have advanced to the point where bids for the dome can be called for this fall; and bids for the framework by the first of the year. When the dome is completed, the mirror will be transported to Mount Hamilton, where it will be ground and polished.

Lick astronomers will undertake with the instrument a collaborative program of research with Mount Wilson and Mount Palomar scientists on the vast new problems opened up by the availability of the huge new telescopes.

### Amateur Astronomers in Germany Surmont Difficulties

Berlin amateur astronomers are making progress in observing the sky in spite of great difficulties. Three letters have been received recently by Wm. L. Dutton, secretary of the Stanford Amateur Astronomers, from astronomers in the American Sector of Berlin.

The group consists of about 30 working members from 12 to 35 years in age, who in the past two years have labored in spare time and all day Sundays to remove the rubbish of a bombed house and make the basement usable. The front garden has been cleared and a platform to support telescopes constructed from salvaged portions of houses. These telescopes constitute the astronomical observatory of the Wilhelm Föerster Institute, licensed by the American Military Government of Berlin. The managers are Mr. Hans Mühle, and Mr. Hans Rechlin. The senior astronomer is Richard Sommer, almost 50 years an astronomer, and Director of the Zeiss Planetarium of Berlin for 15 years until it was destroyed by bombs in 1943. They hope to make the Institute the central observatory of the three non-Soviet zones.

The blockade of Berlin made cement and other essentials unobtainable. Benches and chairs were made from torn lumber. Walls were slowly hand built with salvaged stone in spare time by the able-bodied men. The supply of treasured optics is good. They have built from elementary parts, at no cost in money, six refracting telescopes ranging from 2½ to 8 inches in aperture, and one seven-inch reflector, with others partly built. The supporting tube for a 12-inch reflector that is being built was a metal cylinder pulled out from under some ruins, and adapted.

Some lectures are delivered by a popular astronomer, Robert Henseling (and others), and the cleared area is often found to be too small for the audience. The observing program is simple, using the Sun, Moon, and Planets mainly, as their *greatest* need is for recent and current star charts, tables, pictures, and books on astronomy. The Stamford Amateur Astronomers are getting together at the Stamford Museum all such material that can be spared by anyone interested. For serious, advanced work they lack chronometers, micrometers, photocells, spectroscopic and photographic equipment.

These rugged survivors of the war and blockade are slowly but surely lowering the international barriers to the interesting, valuable, and cultural study of the heavenly bodies.

# Book Reviews

**Die Veränderlichen Sterne der nördlichen Milchstrasse, Teil V.,** by P. Ahnert, C. Hoffmeister, E. Rohlfs, and A. vand de Vorde. (Published at the Observatory of the German Academy of Science of Berlin at Sonneberg.)

This separate publication contains part five of a series whose purpose is to establish the basis for a statistical study of variable stars. The approximately 600 cases of variability of light in stars dealt with here were nearly all discovered at the Sonneberg Observatory. Whenever possible the elements of the light variation are given and the light curves are shown. In cases of irregular variation, the characteristic features are briefly described. Extensive statistical results are not included, because they are to be published in another part.

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**A New Popular Star Atlas.** (Gall and Inglis, 12 Newington Road, Edinburgh, Scotland, and 13 Henrietta Street, Strand, London, W.C.2. Price 5/—.)

This atlas consisting of 16 maps, covering the whole heavens, and showing stars down to magnitude 5½, and also nebulae which are visible in field glasses, seems much like a small-sized Norton's Star Atlas, issued by the same publishers. This smaller atlas contains the essentials for the beginner in astronomy in convenient form. The objects of special interest on each map are listed and described. There is appended an index to the constellations. Also some hints on the care and use of small telescopes and binoculars are given for those who are so fortunate as to possess such instruments. As the student advances he will need a more detailed volume but this affords an excellent starting point.

—C.H.G.

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### Establishment and Maintenance of the Electrical Units

A description of the new system of electrical measurement using "absolute" units, adopted by the International Conference of Weights and Measures and officially instituted January 1, 1948, is described in a new booklet, "Establishment and Maintenance of the Electrical Units," just published by the National Bureau of Standards and available from the U. S. Government Printing Office.

The purpose of this booklet is to record an account of the working of the international system of electrical units, with particular reference to the maintenance of the international units in the 37 years preceding the adoption of the new units; to point out the trends of development that made them obsolete; and to record the official steps by which they were superseded. Also described are the methods used in the measurements that now form the basis for the new absolute units, in which all certifications for standards and instruments are now given by the National Bureau of Standards. In addition, United States laws, important conferences and resolutions pertaining to the adoption of the new units are reproduced in the appendices of the booklet.

Circular C475 "Establishment and Maintenance of the Electrical Units," by F. B. Silsbee, 38 large double-column pages, illustrated with 23 diagrams, halftones, and tables, 25 cents a copy, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Remittances from foreign countries must be made in United States exchange and must include an additional sum of one-third the publication price to cover mailing costs.

National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C.

**Research and Development in Applied Optics and Optical Glass at the National Bureau of Standards,** A Review and Bibliography, by Irvine C. Gardner and C. H. Hahner.

The above is the descriptive title of a 20-page pamphlet recently issued as Miscellaneous Publication 194 of the National Bureau of Standards. We take the following paragraph from the pamphlet itself.

> "A general account of the research and development work in technological optics that has been completed at the National Bureau of Standards. Noteworthy accomplishments that are mentioned include the production of a 70-inch optical disk (at the time of manufacture the largest produced in this country) for Ohio Wesleyan University; a comprehensive study of the relation between chemical composition and index of refraction of optical glass; a study of the relation between annealing temperature and index; the design and construction of an f/6.3 airplane camera lens of 50-inch focal length which resolves railroad ties and shows individuals from a height of nearly two miles; the design and construction of large interferometers; the construction of a special laboratory for testing range finders and similar tasks. A list of 195 Bureau publications pertaining to optical glass and optical instruments is included."

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**Comets in Old Cape Records,** by Donald McIntyre. (Cape Times Limited, Cape Town, Union of South Africa, 1949. 16 pp. 4 plates.)

This pamphlet will be interesting reading for all with a taste for the history of astronomy. Mr. McIntyre has searched the archives of the old Dutch Cape Colony for records of comets. He has found observations of the comets of 1652, 1664, 1682 (Halley's comet), 1686, 1689, 1695, 1733, and 1742. For four of these comets, observations preceding the previously accepted discovery dates were uncovered.

An interesting coincidence concerning Halley's comet is recorded thus:

". . . The very last observations of the comet at this apparition (1835) were made by Sir John Herschel from his station at Claremont, Cape, in May, 1836. Sir John Herschel's little refractor may thus be said to have said goodbye to Halley's comet in 1836. It may also be said to have welcomed the comet back 73 years later; for it was the guiding telescope to the larger instrument at the Helwan Observatory, near the famous pyramids of Sakkara, with which the comet was first photographed on 1909 Aug. 24 on the occasion of its last return."

In a postscript, Mr. McIntyre has rescued from oblivion the name of Faraguet, of Port Louis on the island of Mauritius, who discovered the comet of 1830, and calculated its orbit. Faraguet never received credit for this, because his observations were sent to Europe by Professor Dabadie of the Royal College of Port Louis, and were published as Dabadie's own.

JOSEPH ASHBROOK.
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**Atomic Energy Levels**

A critically evaluated compilation of all known data on the energy levels of elements of atomic number 1 through 23 has recently been published by the National Bureau of Standards and is now available from the U. S. Government Printing Office. Designed to meet the needs of workers in nuclear and atomic physics, astrophysics, chemistry, and industry, the publication is an up-to-date

compendium of all energy levels for these elements exclusive of those due to the hyperfine structure ascribed to atomic nuclei.

The present volume is the first of a series being prepared at the Bureau as part of a general program on atomic energy levels derived from observations of the optical spectra of atoms and ions. Section 1 of this volume (hydrogen through fluorine) has previously been published separately. The new series, represents the cooperative effort of scientists throughout the world and will constitute the first compilation of atomic energy levels in the last 18 years, during which time the number of known energy levels has increased by a factor of 4 or 5.

In this series, spectra are presented in order of increasing atomic number, and under a given atomic number they are listed in order of increasing stages of ionization. For each spectrum a selected bibliography covering the analysis is given. The energy levels are tabulated in the related groups that form spectroscopic terms, counting upward from the lowest as zero. Electron configurations are also given in the tables, together with term intervals, Lande $g$-values, and term designations in a uniform notation. For the more complex spectra, arrays of observed terms and their electron configurations are included. Similar arrays of the terms predicted by theory for important isoelectronic sequences are given in the introduction.

Volume 1 (containing Sections 1-3) of the National Bureau of Standards Circular 467, entitled *Atomic Energy Levels,* by Charlotte E. Moore, 352 large 2-column pages, cloth-bound, can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of $2.75 a copy. Remittances from foreign countries must be in U. S. exchange and must include an additional sum of one-third the publication price to cover mailing costs.

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